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GENERAL ELECTRIC CO.
Instrumentation & Control
228 W. Florence Ave.
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Instruction Manual

MODEL 821A
DIFFERENTIAL VOLTMETER

FLUKE
ELECTRONICS FOR INDUSTRY
INSTRUMENTS / COMPONENTS

JOHN FLUKE MFG. CO. INC.
P.O. Box 7428 Seattle, Washington 98133

May 1, 1963

MODEL 821A
DIFFERENTIAL VOLTMETER

821A _____ and above
821AR _____ and above
821A/AG _____ and above
821AR/AG _____ and above

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ADDENDUM

FLUKE MODELS

801B, 803B, 803D, 821A, 823A, and 825

The DC Differential Voltmeter Calibration procedure is ammended to employ the Fluke Model 332A DC Voltage Calibrator in lieu of the several instruments listed in section IV of the manual.

Procedures included in the manual call for the use of an Eppley standard cell, a galvonometer, two silver contact push-button switches, two resistors, a precision voltage divider and a power supply. The procedure is complex, requiring four expensive standards, and introduces error possibilities if considerable care is not exercised in assembling the set-up.

The Fluke Model 332A DC Voltage Calibrator provides, in one instrument, a reliable 0.003% accuracy over the entire range of DC input of the test instrument.

Generally, operation of the Model 332A DC Voltage Calibrator involves simply connecting the input of the instrument under test to the Model 332A output and dialing the desired voltage level on the Model 332A. As an example, consider calibration of the Model 803B on its 50 volt range.

a. Set the VOLTAGE RANGE dials of the Model 332A to 50 volts.

b. Connect the Model 803B INPUT to the Model 332A OUTPUT.

c. Set the Model 803B as follows:

RANGE	50
NULL	0.01
voltage readout dials	49.9910

d. Set the POWER switch of the Model 332A to STANDBY/RESET and then to ON.

e. Null the Model 803B by adjusting 50 V DC ADJ control R323.

For more detailed operation procedures consult the instruction manual for the Model 332A DC Voltage Calibrator and the manual for the instrument under test.

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821A & 821A/AG

821AR & 821AR/AG

SECTION I

INTRODUCTION AND SPECIFICATIONS

1-1. INTRODUCTION

a. This instruction manual is for use with the 821A series Differential DC Voltmeters. These are available in either a cabinet model or a standard 19 inch rack model, and with either a standard cell or a Zener diode as the reference element. Model designations are: 821A (cabinet model, standard cell); 821AR (rack model, standard cell); 821A/AG (cabinet model, Zener diode); and 821AR/AG (rack model, Zener diode).

b. The high accuracy, portability, and compactness of the 821A make this instrument ideal for the precise measurement of almost any DC voltage. Ease of operation, inherent protection from accidental overload, and high reliability contribute to the outstanding performance that assures suitability for both production line testing and precision laboratory measurements. This instrument is capable of being used as a vacuum tube voltmeter, as a precision potentiometer, and as a megohmmeter for measurement of high resistance. It can also be used to measure the excursions of a voltage about some nominal value. One feature that should be emphasized is that no current is drawn from the unknown source when balance is attained. Thus the determination of the unknown potential is independent of its source resistance. The 821A is basically used for measurements of DC voltages from 0 to 500 volts. However, high accuracy measurements to 30,000 volts DC are possible with precision voltage dividers especially designed for use with the Fluke Model 800 Series Differential Voltmeters. As additional features, this instrument contains a polarity switch for equal convenience in measuring positive or negative voltages and an adjustable recorder output which makes the 821A particularly useful for monitoring the stability of almost any DC voltage. Furthermore, the 821A meter has taut-band suspension which eliminates problems due to meter stickiness.

c. When used as a differential voltmeter, the 821A operates on the potentiometric principal. An unknown voltage is measured by comparing it to a known adjustable reference voltage with the aid of a null detector. An accurate standard for measurements is obtained by setting the reference supply with a standard cell for the 821A and 821AR and with a Zener reference diode for the 821A/AG and 821AR/AG. The known adjustable reference voltage is provided by a 500 volt DC power supply and five Kelvin-Varley decade resistor strings that are set accurately by five voltage readout dials. In this way, the 500 volts can be precisely divided into increments as small as 10 microvolts. The unknown voltage is then simply read from the voltage dials. In the highest null sensitivity range, potentional differences between the unknown and the reference voltage of only 0.001 volts will cause full scale meter deflection.

d. The instrument is normally supplied ready for use on 115 volts. Upon request, instruments are supplied for 230 volts operation. If it becomes desirable to convert from one mode of operation to the other, refer to the instruction decal on the back of cabinet models or on the cover in rack models.

1-2. DAMAGE IN SHIPMENT

Immediately upon receipt, thoroughly inspect for any damage that may have occurred in transit. If any damage is noted, follow the instructions outlined on the warranty page at the back of this manual.

1-3. SPECIFICATIONS

AS A PRECISION POTENTIOMETER

ACCURACY: ±0.01% of input voltage from 0.5 volt to 500 volts. ±(0.01% + 10 uv) below 0.5 volt.

RANGE:

Input Voltage Range	Null Range	Input Resistance per volt of input voltage	
		At Null	1% of Full Scale Off Null
50-500	10-0-10	Infinite	100 Meg
	1-0-1	Infinite	1,000 Meg
5-50	1-0-1	Infinite	1,000 Meg
	0.1-0-0.1	Infinite	10,000 Meg
0.5-5	0.1-0-0.1	Infinite	10,000 Meg
	0.01-0-0.01	Infinite	100,000 Meg
0-0.5	0.01-0-0.01	Infinite	100,000 Meg
	0.001-0-0.001	Infinite	100,000 Meg

RESOLUTION: Voltage Readout Dial Resolution

Range Setting	Null Setting	Resolution
500	any	10 mv
50	any	1 mv
5	any	0.1 mv
0.5	any	0.01 mv

Meter Resolution (1/4 of a small scale meter division)		
Range Setting	Null Setting	Resolution
any	10	50 mv
any	1	5 mv
any	0.1	0.5 mv
any	0.01	0.05 mv
any	0.001	0.005 mv

AS A VACUUM TUBE VOLTMETER

ACCURACY: 3% on all ranges

RANGE:

Voltage Ranges	Input Resistance
500-0-500	50 Meg
50-0-50	50 Meg
5-0-5	50 Meg
0.5-0-0.5	50 Meg
10-0-10*	10 Meg
1-0-1*	10 Meg
0.1-0-0.1*	10 Meg
0.01-0-0.01*	10 Meg
0.001-0-0.001*	1 Meg

*These ranges are obtained by using Null ranges with all five voltage readout dials set to 0.

GENERAL SPECIFICATIONS

STABILITY OF REFERENCE SUPPLY:

±0.0025% for a 10% change in line voltage.
±0.005% per hour after 30 minute warmup.

STABILITY OF METER ZERO:

±0.25% of full scale for a 10% change in line voltage.

OPERATING TEMPERATURE RANGE:

Model 821A and 821AR (Standard cell reference element). Within DC accuracy specifications from 55°F to 95°F, derated at 0.0004%/°F outside these limits to 35°F and 110°F.

Model 821A/AG and 821AR/AG (Zener diode reference element). Within DC accuracy specifications from 55°F to 95°F, derated at 0.0005%/°F outside these limits to 0°F and 125°F.

RELATIVE HUMIDITY:

Within specifications from 0 to 80% relative humidity.

SHOCK AND VIBRATION:

Meets requirements of MIL-T-945A.

INPUT POWER:

115/230 volts AC (105-130/210-260 volts AC), 50-440 cps, 60 watts.

DIMENSIONS:

Cabinet Model - 13" high, 9-3/4" wide, 14" deep.
Rack Model - 7" high, 19" wide, 14" deep.

WEIGHT:

Cabinet Model - 23 lbs.
Rack Model - 21 lbs.

SECTION II

OPERATING INSTRUCTIONS

2-1. CONTROLS, TERMINALS, AND INDICATORS

The location, circuit symbol, and a functional description of external controls, terminals, and indicators on the 821A Precision Differential DC Voltmeter may be found in figure 2-1.

CONTROLS TERMINALS AND INDICATORS	LOCATION	CIRCUIT SYMBOL	FUNCTIONAL DESCRIPTION
Input terminals	Front panel	J1, J2	Provided for connecting DC voltage to be measured.
Chassis ground terminal	Front panel	J3	Provided for grounding purposes. A 0.47 uf capacitor is connected from the lower input binding post to the chassis ground post. The upper input post should never be connected to the chassis ground post. Since the instrument is equipped with a three-wire line cord with the third wire fastened to the chassis, the external circuit should be checked for conflicts in grounding before connecting lower input binding post (middle post) to the chassis post.
Power toggle switch	Front panel	S1	Applies AC line voltage to the primary circuit of the power transformer.
OPERATE-CALIBRATE switch	Front panel	S4	Remains in the OPERATE position at all times except when it is necessary to calibrate the internal 500 volt DC reference supply. When held in the CALIBRATE position, a representative sample of the reference voltage is compared to the voltage of an internal standard cell, or Zener reference diode for the /AG models, and any difference is indicated on the meter.
CALIBRATE control	Front panel	R2	Varies the output of the 500 volt DC reference supply. When the OPERATE-CALIBRATE switch is held in the CALIBRATE position, the reference supply is accurately set by adjusting the CALIBRATE control for zero meter deflection.
RANGE switch	Front panel	S2	Selects desired voltage range. Full scale voltage ranges of 500, 50, 5, and 0.5 volts are available.

Figure 2-1. CONTROLS, TERMINALS, AND INDICATORS (Sheet 1 of 2)

CONTROLS TERMINALS AND INDICATORS	LOCATION	CIRCUIT SYMBOL	FUNCTIONAL DESCRIPTION
NULL switch	Front panel	S3	Set to VTVM for determining the approximate value of unknown voltage prior to differential measurements. Five null voltage ranges of 10, 1, 0.1, 0.01 and 0.001 volts are used for differential measurements. These ranges represent full scale differences between the unknown voltage and the amount of precision internal reference voltage that is set on the voltage readout dials.
A, B, C, D, and E voltage readout dials	Front panel	S6, S7, S8, S9, S10	Provide an in-line readout of the amount of internal reference voltage necessary to null the unknown voltage.
Decimal lights	Front panel	DS1, DS2, DS3, DS4	Serve as decimal points for the voltage readout dials. A different light illuminates for each position of the RANGE switch.
Polarity switch	Front panel	S5	Changes polarity of 821A to match polarity of unknown voltage. With this switch in the positive position, the polarity of the upper input binding post is positive with respect to the lower input binding post (middle post).
Output terminals	Rear panel of cabinet models, front panel of rack models.	J4, J5	Provided for attaching a recorder to monitor voltage excursions.
Output level control	Rear panel of cabinet models, front panel of rack models.	R1	Varies the output level of the output binding post from 0 to approximately 20 millivolts at full scale deflection.
Meter	Front panel	M1	Indicates approximate voltage when 821A is in VTVM mode and difference between unknown and internal reference voltage when 821A is in differential mode. The upper scale, 500-0-500, is used when the NULL switch is set to VTVM. At all other times, the lower scale, 1-0-1, is used.
Mechanical zero control	Meter case	None	Sets meter to zero mechanically. This adjustment should be used only after instrument has been turned off for at least three minutes or when the internal meter terminals have been shorted.
Fuse	Rear panel of cabinet models, front panel of rack model.	F1	Fuse holder protrudes from instrument to provide easy access to the fuse. The fuse is a one ampere slow blowing type for 115 volt operation and a 0.5 ampere slow blowing type for 230 volt operation.

Figure 2-1. CONTROLS, TERMINALS, AND INDICATORS (Sheet 2 of 2)

2-2. ZEROING INSTRUCTIONS

From time to time, it may be necessary to adjust the internal meter zero control. This will normally be done at somewhat more frequent intervals than regular calibration for 821A & 821A/AG serial numbers 123 to 421 and 821AR & 821AR/AG serial numbers 123 to 372. For later instruments, it should only be necessary to adjust the internal meter zero during regular calibration. Proceed as follows:

a. Mechanically zero the meter with the adjustment screw on the front of the meter case. If the instrument

is in the case, it must be shut off for at least three minutes prior to this adjustment. If out of case, another method would be to short out the internal meter terminals prior to zeroing.

b. Set power switch to ON and allow a 20 minute warmup period.

c. Set RANGE switch to 5 or 0.5 volts, voltage readout dials to zero, and NULL switch to 0.001 volt.

d. Adjust R212 (R232 for 821A & 821A/AG serial numbers 123 to 421 and 821AR & 821AR/AG serial numbers 123 to 372), VTVM ZERO ADJ, for zero meter deflection. This control may be reached through the ventilation holes in the cabinet model (see figure 4-7). In the rack model, an identified access hole is provided on the rear panel. An insulated screwdriver must be used to reach the control. This is done to prevent shorting control to chassis ground.

2-3. PRELIMINARY OPERATION

The following procedure prepares the voltmeter for operation:

a. Connect power plug to a 115 volt AC power source. If instrument has been wired for 230 volt operation, connect to 230 volts AC.

NOTE

The round pin on polarized three-prong plug connects instrument case to power system ground. Use a three-to-two pin adapter when connecting to a two-contact receptacle. For personnel safety, connect short green lead to a good earth ground.

b. Set controls on 821A voltmeter as follows:

RANGE	500 volts
NULL	VTVM
polarity	+ (positive)
all voltage readout dials	0 (zero)
power	ON

c. After a warmup period of at least ten minutes, advance OPERATE-CALIBRATE switch against spring tension to CALIBRATE, and adjust internal 500 volt DC reference supply with CALIBRATE control for zero meter deflection. Release OPERATE-CALIBRATE switch.

2-4. OPERATION AS A DIFFERENTIAL VOLTMETER

a. After completing preliminary operation, connect unknown voltage to input binding posts. If one side is grounded, always connect it to the lower input post (middle post).

b. Turn RANGE switch to lowest range that will allow an on-scale reading and note approximate value of unknown voltage as indicated on upper meter scale.

c. If meter reads to the left, turn polarity switch to the negative position. The meter needle will deflect to the right. This is because polarity of unknown voltage is negative.

d. Noting the position of illuminated decimal light, set five voltage readout dials to approximate voltage determined in step b. For example, if approximate voltage is 35 volts, the decimal light between the B and C voltage readout dials will be illuminated. Therefore, set A dial to 3, B dial to 5, and C, D, and E dials to 0.

e. Set NULL switch to successively more sensitive null ranges, as indicated in figure 2-2, and adjust voltage readout dials for zero meter deflection in each null position. When the meter needle indicates to the right, the voltage under measurement is greater than the voltage set on the voltage readout dials. When the indication is to the left, the voltage is less than that set on the readout dials.

f. Read unknown voltage directly from the five voltage readout dials.

INPUT VOLTAGE RANGE	*RECOMMENDED NULL SETTING
50-500	10 then 1 (then 0.1 for voltages from 50 to 100 volts)
5-50	1 then 0.1 (then 0.01 for voltages from 5 to 10 volts)
0.5-5	0.1 then 0.01 (then 0.001 for voltages from 0.5 to 1 volt)
0-0.5	0.01 then 0.001

*Any null range may be used with any input voltage range; recommended settings are those most useful.

Figure 2-2. RECOMMENDED NULL SETTINGS

2-5. OPERATION AS A CONVENTIONAL VTVM

If it is desired to use the instrument as a VTVM only, additional ranges can be made available by converting the NULL ranges to VTVM ranges. This is made possible by setting the voltage readout dials to zero. Proceed as follows:

a. Perform preliminary operation as stated in paragraph 2-3.

b. Consult figure 2-3, and select full scale voltage deflection desired. If the approximate value of the voltage to be measured is unknown, select the 500 volt range initially.

c. Set RANGE switch, NULL switch, and voltage dials as indicated for the range selected.

d. Connect voltage to be measured to input binding posts. Deflection to the right indicates that unknown DC voltage is of positive polarity.

e. Read voltage from upper or lower scale as listed in figure 2-3.

FULL-SCALE DEFLECTION	RANGE SWITCH	NULL SWITCH	VOLTAGE DIALS	METER SCALE
DC				
500-0-500	500	VTVM	No effect	Upper
50-0-50	50	VTVM	No effect	Upper
5-0-5	5	VTVM	No effect	Upper
0.5-0-0.5	0.5	VTVM	No effect	Upper
10-0-10	No effect	10	All zero	Lower
1-0-1	No effect	1	All zero	Lower
0.1-0-0.1	No effect	0.1	All zero	Lower
0.01-0-0.01	No effect	0.01	All zero	Lower
0.001-0-0.001	No effect	0.001	All zero	Lower

Figure 2-3. VTVM RANGES

2-6. MEASUREMENT OF VOLTAGE EXCURSIONS ABOUT A NOMINAL VALUE

a. Perform preliminary operation as stated in paragraph 2-3.

b. Connect voltage to be observed to input binding posts. If meter reads to the left, the voltage being measured is negative; set polarity switch to the negative position in this case. This will cause meter pointer to deflect to the right.

c. Set RANGE switch to lowest range which will give an on-scale meter indication and note nominal value of voltage indicated.

d. Set the five voltage readout dials to nominal voltage.

e. Turn NULL switch to lowest position that will allow voltage excursions to remain on scale.

f. Read voltage excursions from meter. Note that full scale right and left meter deflections are equal to the NULL voltage setting. Meter deflection to the right indicates that the voltage under observation has increased above the nominal value while deflection to the left indicates it has decreased.

2-7. RECORDING VOLTAGE EXCURSIONS

a. GENERAL. Recorder output binding posts and an output level control are provided on the 821A for monitoring the excursions of an unknown voltage from the voltage indicated by the voltage readout dial settings. If the leakage resistance between the recorder and ground is less than 10,000 megohms, the accuracy of the voltmeter will be impaired. Therefore, the FLUKE Model A88 Isolation Amplifier is recommended for this application. The A88 will allow the use of a wide range of strip chart recorders for recording the voltmeter reading without regard to the input isolation characteristics of the recorder.

b. USE OF 821A WITH A88 AND A RECORDER. To use the A88 Isolation Amplifier and a recorder with the 821A, proceed as follows:

(1) Set A88 POWER switch to ON.

(2) When batteries are being used as a power source for A88, measure voltage at BATT TEST jacks. If voltage is between 11.7 and 14 volts DC, the batteries are satisfactory for use. However, if battery voltage is below 12.8 volts, batteries are approaching end of their useful life and should be replaced.

(3) Connect output terminals of differential voltmeter to INPUT terminals of isolation amplifier with teflon leads.

(4) Connect OUTPUT terminals of isolation amplifier to recorder input terminals.

(5) Perform preliminary operation as stated in paragraph 2-3.

(6) Short input terminals of 821A and set switches on 821A as follows:

polarity	+ (positive)
RANGE	50
NULL	10
voltage readout dials	10.000

The 821A meter will indicate full scale. This provides up to a maximum of at least 18 millivolts at the output terminals depending on setting of the output level control.

(7) Turn on recorder and set recorder gain so that a recorder input of either ±2 volts or near maximum if maximum is below ±2 volts will cause recorder deflection desired for full scale deflection of differential voltmeter.

(8) Adjust output level control on differential voltmeter until recorder deflection obtained is that desired to correspond to full scale deflection of the differential voltmeter.

(9) Remove short from input terminals of the 821A.

The voltmeter and recorder are now ready for recording the measurement of voltage excursions about a nominal value. Proceed as instructed under paragraph 2-6.

c. USE OF 821A WITH A RECORDER. To use a recorder with the 821A, proceed as follows:

(1) Connect 821A output terminals to input terminals of recorder with teflon leads.

CAUTION

Do not ground either of the 821A recorder output terminals or either of the recorder input terminals. If any of these terminals are grounded, current will be drawn from the 821A Kelvin-Varley voltage divider and the 821A will no longer be accurate.

(2) After connecting the recorder, perform preliminary operation as stated in paragraph 2-3.

(3) Check for excessive leakage as follows:

(a) Connect a DC voltage to the input of the 821A and differentially measure its potential in a recommended null range.

(b) Alternately connect and disconnect the recorder leads from the output terminals of the 821A while noting the meter needle deflection. More than one-quarter of a small scale division deflection indicates that excessive leakage has been introduced by the recorder. This will impair the accuracy of the 821A voltmeter.

(c) Disconnect the voltage.

(4) After the leakage test has been successfully completed, short input terminals of 821A.

(5) Set switches on 821A voltmeter as follows:

polarity	+ (positive)
RANGE	50
NULL	10
voltage readout dials	10.000

The 821A meter will indicate full scale deflection. This provides up to at least 18 millivolts at the output terminals depending on the setting of the output level control.

(6) Turn output level control until recorder deflection obtained is that desired to correspond to full scale deflection of 821A.

(7) Remove short from input terminals of 821A. The 821A and recorder are now ready for combined use. Proceed as instructed under paragraph 2-6.

2-8. MEASUREMENT OF HIGH RESISTANCES

One of the important features of the 821A voltmeter is its ability to be used as a megohmmeter for rapidly measuring high resistances from 1 megohm to 250,000 megohms. The following equation may be used to compute the resistance in megohms of an unknown connected to the input binding posts:

$$R_x = 10 \left(\frac{E}{E_m} - 1 \right) \text{ megohms,}$$

where:

R_x = unknown resistance in megohms

E = voltage indicated by voltage readout dials

E_m = voltage indicated on meter

10 = megohms of input resistance of VTVM circuit on 10, 1, and 0.1 null range.

When connecting the unknown resistance to the input terminals, use short isolated leads to prevent measuring leakage resistance between the leads.

a. FROM 1 MEGOHM TO 500 MEGOHMS. For rapid measurement of resistances from 1 megohm to 500 megohms, proceed as follows:

(1) Perform preliminary procedure as stated in paragraph 2-3.

(2) Set RANGE switch to 500 and NULL switch to 10.

(3) Connect unknown resistance between input terminals.

(4) Adjust voltage readout dials for full scale meter deflection.

(5) Subtract 10.00 from the amount set on the voltage readout dials to find the resistance of the unknown in megohms.

b. FROM 500 MEGOHMS TO 5000 MEGOHMS. For rapid measurements, of resistances from 500 to 5000 megohms, proceed as follows:

(1) Perform preliminary procedure as stated in paragraph 2-3.

(2) Set RANGE switch to 500 and NULL switch to 1.

(3) Connect unknown resistance between input terminals.

(4) Adjust voltage readout dials for full scale meter deflection.

(5) Subtract 1.00 from the amount set on the voltage readout dials and multiply the result by 10 to find the resistance of the unknown in megohms.

c. FROM 5,000 MEGOHMS TO 50,000 MEGOHMS. For rapid measurement of resistances from 5,000 to 50,000 megohms, proceed as follows:

(1) Perform preliminary procedure as stated in paragraph 2-3.

(2) Set RANGE switch to 500 and NULL switch to 0.1.

(3) Connect unknown resistance between input terminals.

(4) Adjust voltage readout dials for full scale meter deflection.

(5) Multiply the amount set on the voltage readout dials by 100 to find the resistance of the unknown in megohms.

d. FROM 50,000 MEGOHMS TO 250,000 MEGOHMS. To determine the value of an unknown resistance between 50,000 megohms and 250,000 megohms, proceed as follows:

(1) Perform preliminary procedure as stated in paragraph 2-3.

(2) Set RANGE switch to 500 and NULL switch to 0.1.

(3) Connect unknown resistance between input terminals.

(4) Adjust voltage readout dials for a convenient meter deflection.

(5) The resistance in megohms may be calculated by substituting the meter reading in volts (E_m, 0 to 0.1 volt on bottom scale) and the voltage readout dial setting

(E) into the following equation:

$$R_X = 10 \frac{E}{E_m} \text{ megohms}$$

2-9. NOTES ON MEASURING VOLTAGES

a. ADJUSTMENT OF 500 VOLT SUPPLY. The 500 volt DC reference supply may be adjusted (paragraph 2-3, step c) at any time deemed necessary without heed to the position of the switches and without removing any input or output connections. However, until the instrument has warmed up to an equilibrium temperature (about 1/2 hour), it should be adjusted prior to each specific measurement for best accuracy. When making prolonged measurements, allow one hour warmup time to insure that 500 volt reference supply does not shift during the final warmup phase.

b. GROUND LOOP PRECAUTIONS. Ground loop currents should be avoided to assure accuracy when making measurements. Potential differences are often found at different points on power system grounds. When this is the case, current may flow from the power system ground through the 821A and the equipment under measurement and back to the power system ground. To avoid this when system being measured is grounded, do not connect 821A input binding posts to chassis ground post.

c. USE OF SHORTING LINK. A 0.47 uf capacitor (C1) is connected from the lower input binding post to the chassis ground post to reduce the effect of circulating AC currents from the transformer. In some cases, it is possible for C1 to acquire a charge. For example, C1 will become charged through leakage resistance over a period of time if there is no external connection to the input terminals and the controls are set as follows: range to 500, null to any null range, polarity to +, and voltage readout dials to several hundred volts. This condition may cause an error on low level measurements (under 5 volts) due to C1 discharging through the Kelvin-Varley divider. Connecting the shorting link from the lower input post to the ground post will discharge C1 and thus prevent an inaccurate indication.

d. RECOMMENDED NULL RANGES. Certain null ranges are recommended for use with each setting of the RANGE switch for the following reasons. With the RANGE switch at 500 volts, the last voltage readout dial (E) changes the reference voltage in steps of 0.01 volt. Therefore, the unknown voltage would have to be an exact multiple of 0.01 volt if a null is to be obtained on the 0.1, 0.01, or 0.001 volt NULL range. Furthermore, it is unlikely that an unknown voltage of a few hundred volts will be stable within 10 millivolts. Finally, the regulation of the reference supply is approximately 0.0025%, or ±0.0125 volt for a 10% change in line voltage. Although this is more than adequate when the instrument is used in the recommended way, a badly fluctuating line voltage may cause the 821A to meter the regulation of its own 500 volt reference supply. For example, when measuring 500 volts, a line change of 10% may cause the 500 volt reference supply to change as much as 12.5 mv. Although this is small, the 821A will indicate full scale for a change as little as 100 mv, 10 mv, or 1 mv if attempting to use the 0.1, 0.01, or 0.001 null ranges.

e. EFFECT OF AC COMPONENTS. An AC component of several times the unknown DC may be present on the unknown and the 821A will always indicate well within the specifications for frequencies over a few hundred cycles. An AC component may have an adverse effect if it is of a low frequency or if it has a frequency that is a multiple or submultiple of the chopper frequency. A double section low pass filter (R201, C201, R202, and C202) is used at the input of the null detector to reduce any AC present on the DC being measured. At lower frequencies, this low pass filter is less effective and the magnitude of the AC component is more significant. If this frequency is below 100 cycles, the accuracy may no longer be with specifications. For example, a 60 cycle AC voltage that is 1% of the input will cause an error of approximately 0.001% which is well within the specifications. Also, since the input attenuation is less on the more sensitive null settings, the accuracy may be affected only on the more sensitive null settings. When the frequency is very close to a multiple or submultiple of the chopper frequency (approximately 83 cycles), the meter needle will oscillate at the difference frequency. If AC components that affect the accuracy are ever encountered, additional filtering will be required. For an AC of a single frequency, a twin-T filter is effective and has the advantage of low total series resistance. For an AC variable frequency, an ordinary low pass filter may be used. In either case, high quality capacitors of high leakage resistance should be used.

f. MEASUREMENT OF NEGATIVE VOLTAGES. Because of a polarity switch, voltage which are negative with respect to ground as well as the more commonly encountered positive voltages may be measured with equal facility. If the upper input post is connected to the metal case, either at the 821A or at the source under measurement, the accuracy of the voltmeter may be reduced. However, with the polarity switch, the upper input post never has to be connected to ground. If the unknown voltage is grounded, always connect the grounded side to the lower input post (middle post) and use the polarity switch to obtain the proper result.

SECTION III

THEORY OF OPERATION

3-1. GENERAL

a. Figure 3-1 shows the block diagram for the 821A Differential Voltmeter. As seen in this figure, the circuit is mainly composed of a sophisticated DC vacuum tube voltmeter (vtvm) and an extremely accurate 0 to 500 volt reference. The vtvm uses a null detector, an input attenuator, and a meter to obtain high sensitivity. The 0 to 500 volt reference uses a range divider and a Kelvin-Varley attenuator to make the output of a well regulated 500 volt DC power supply adjustable. Refer to the functional schematic following Section VI for more detail. This schematic is designed to aid in the understanding of circuit theory and troubleshooting. The signal flow is from left to right and the components are laid out in a functionally logical manner.

b. The overall operation of the voltmeter may be summarized as follows. To measure the approximate value of a DC voltage, the unknown voltage is connected directly across the DC vtvm input attenuator. This attenuator is set in such a way that the maximum voltage for each range is reduced to a signal of 1 millivolt. The 1 mv signal is applied to the null detector and causes 100 microamperes to flow through the meter for full scale deflection. To accurately measure a DC voltage, the unknown voltage is connected across the series combination of the vtvm and the 0 to 500 volt reference. The reference voltage is then adjusted with the five voltage readout dials until it matches the unknown voltage as indicated by the vtvm.

c. In order to provide for a more complete understanding of the 821A voltmeter, the following paragraphs describe each section of the circuit in detail.

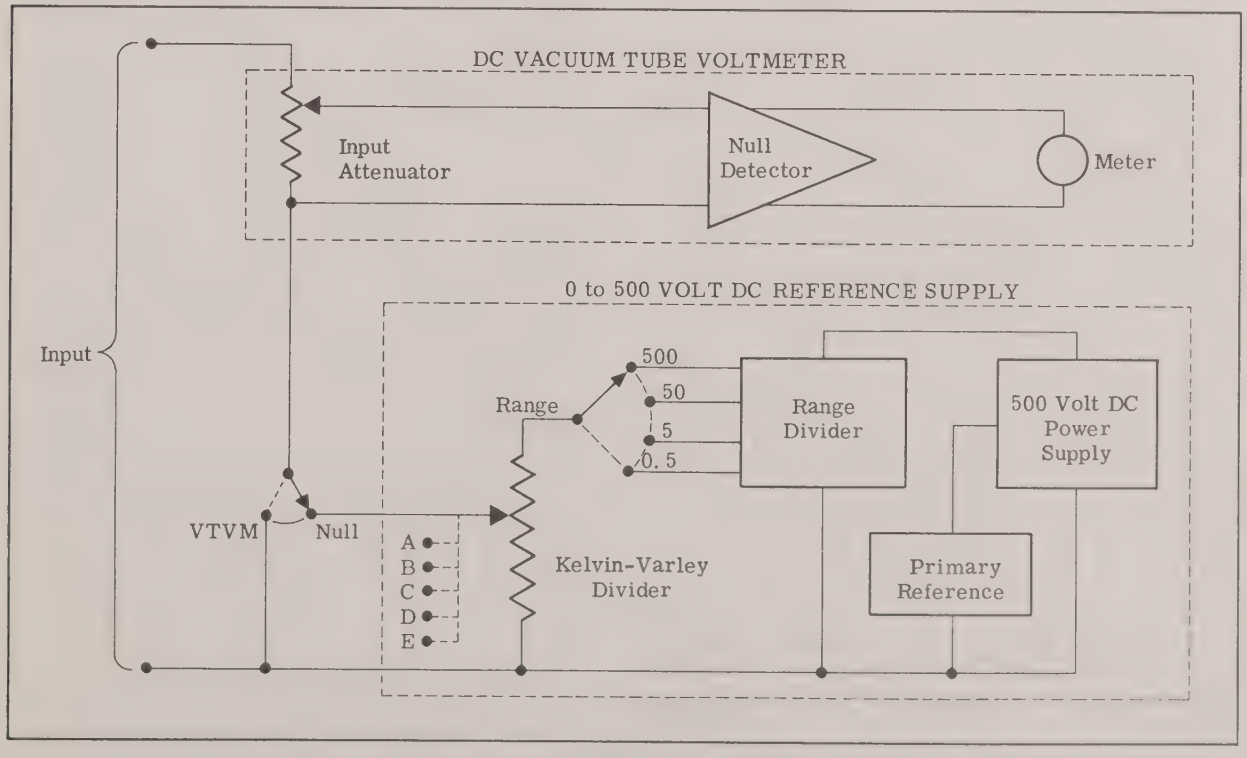


Figure 3-1. 821A DIFFERENTIAL VOLTMETER BLOCK DIAGRAM

3-2. DC VACUUM TUBE VOLTMETER

a. GENERAL. The DC vtvm is composed of an attenuator, a null detector, and meter. The heart of the DC vtvm is the null detector in which the DC signal is modulated, amplified, rectified, and finally filtered to produce a DC output. The null detector has a high amount of negative current feedback. This makes the output current approximately equal to the signal voltage divided by the impedance of the feedback network, regardless of the amplifier characteristics. The high negative feedback also makes the amplifier relatively insensitive to the gain changes in individual stages due to aging and replacement. The output current from the null detector is indicated on a meter that has tautband suspension. This suspension does away with all friction associated with meter pivot stickiness. Thus, any tendency for the meter pointer to stick at one point of the scale and then jump to another point is eliminated. The attenuator is used to reduce the voltage span of each range to a common range usable by the null detector to produce proper meter deflection.

b. NULL DETECTOR FOR 821A & 821A/AG SERIAL NUMBERS 123 TO 421 AND 821AR & 821AR/AG SERIAL NUMBERS 123 TO 372. At the input to the null detector, R201, C201, R202, and C202 form a double section low pass filter that reduces any AC component present on the DC voltage being measured. The difference between the voltage appearing at the output of the filter and the voltage developed across the feedback network is converted to an alternating voltage by G1, an 83 cycle electromechanical chopper. This chopped voltage is amplified by V202A, V202B, and V203A before passing through cathode follower V203B. During half the chopper cycle the output of the amplifier is clamped to approximate null detector common potential by G1 while during the other half the output is filtered by C212 to provide a DC current for the meter. The voltage developed across feedback network R220, R221, and R222 is proportional to the meter (output) current. When the chopper provides connection between contacts 5 and 7, this feedback voltage effectively reduces the magnitude of the voltage that is chopped and applied to the input of the amplifier. The impedance of the feedback network (R220, R221, and R222) is adjustable between 8.82 and 9.83 ohms. Since the output current is approximately equal to the signal voltage divided by the impedance of the feedback network, a 1 mv signal voltage indicates an output current of 101.7 to 113.4 ua. However, there is a loss due to finite amplifier gain and filtering that leaves the output current around 100 ua which can be set accurately by means of the feedback network. Thus, current feedback makes the output current essentially proportional to the signal voltage. For full scale deflection, a 1 mv signal voltage will cause 100 ua to flow through the meter.

c. NULL DETECTOR FOR 821A & 821A/AG SERIAL NUMBERS 422 AND ON AND 821AR & 821AR/AG SERIAL NUMBERS 373 AND ON. At the input to the null detector, R201, C201, R202, and C202 form a double section low pass filter that reduces any AC component present on the DC voltage being measured. The difference between the voltage appearing at the output of the filter and the voltage developed across the feedback network is converted to an alternating voltage by V201 and V202, a series-shunt photochopper. The photochoppers are driven by an astable multivibrator operating at 84 cycles to prevent interference from line frequency pickup. The chopped voltage is amplified by solid state amplifier Q201 through Q205 before being delivered to demodulator photocell V203. During half the chopper cycle, the output of the amplifier is clamped close to null detector common potential by V203 while during the other half the output is filtered by R221 and C211 to provide a DC output. To prevent loading of the chopper amplifier, especially at high temperatures, the filtered output is fed to unity gain amplifier Q206 and Q207 which supplies the necessary meter current. The voltage developed across feedback network R203, R204, and R205 is proportional to the meter (output) current. When DS202 illuminates V202, its resistance drops from about 50M to 5K and the amplifier input is equal to the feedback voltage. When DS203 illuminates V201, its resistance drops from about 50M to 5K and the amplifier input is equal to the output voltage of the input filter. The impedance of the feedback network (R203, R204, and R205) is adjustable between 9.28 and 10.5 ohms. Since the output current is approximately equal to the signal voltage divider by the impedance of the feedback network, a 1 mv signal voltage indicates an output current of 95.1 to 108 ua. The output current is adjusted to 100 ua during calibration by means of the feedback network. Thus, current feedback makes the output current essentially proportional to the signal voltage. For full scale deflection, a 1 mv signal voltage will cause 100 ua to flow through the meter.

d. INPUT ATTENUATOR. In the vtvm mode, four positions on the vtvm attenuator selected by range switch section S2C provide the necessary reduction of the 500, 50, 5, and 0.5 volt ranges for proper null detector input. For this mode, the resistance of the attenuator and thus the input resistance of the 821A is 50 megohms (R3 through R12). In the differential mode, the voltage difference (unknown voltage minus reference voltage) is reduced by four positions on the vtvm attenuator selected by null switch section S3C and S3D to give full scale deflections corresponding to inputs of 10, 1, 0.1, and 0.01 volts. For full scale deflection corresponding to 0.001 volt, the voltage across the attenuator is fed directly to the null detector. Although the resistance of the vtvm attenuator is 10 megohms (R7 through R12) for the 10, 1, 0.1, and 0.01 volt null ranges and the one megohm (R8 through R12) for the 0.001 volt null range; this is not the input resistance of the 821A. The input resistance is determined by dividing the unknown terminal voltage by the current drawn from the unknown. The current drawn from the unknown is equal to the difference between the unknown terminal voltage and the internally known voltage divided by the resistance of the input attenuator. The equation for input resistance can therefore be written as:

$$R_{in} = \frac{E_u}{I_u} = \frac{E_u R_a}{|E_u - E|} = \frac{E_s (R_a + R_s)}{|E_s - E|} - R_s$$

where:

R_{in} = input resistance of voltmeter

E_u = $E_s - I_u R_s$ = terminal voltage of unknown

I_u = current drawn from unknown

E_S = source voltage of unknown

R_S = source resistance of unknown

R_a = resistance of input attenuator

E = voltage indicated by voltage readout dials

$|\ |$ = absolute value (magnitude only)

Since the reference voltage (E) is equal to the unknown voltage (E_u) and the source voltage (E_S) at null, no current is drawn from the unknown and the input resistance is therefore infinite.

e. NULL DETECTOR POWER SUPPLY FOR 821A & 821A/AG SERIAL NUMBERS 123 TO 421 AND 821AR & 821AR/AG SERIAL NUMBERS 123 TO 372. The B+ supply for the null detector is obtained from a half-wave rectifier consisting of diode CR201 and a filter network (C213A, R227, and C213B) that is regulated by an 0A2 tube (V204) and series dropping resistor R230. Divider resistors R228, R229, R231, and R232 and diode CR202 provide a compensating voltage for the purpose of adjusting the null detector to zero with R232 when there is no signal input. Diode CR202 keeps one side of R232 at approximately -0.6 volt DC with respect to the null detector common.

f. The filament of V202 and the chopper drive unit require a stable supply. This is obtained by using a filtered half-wave rectifier (CR203 and C214) that drives a Darlington connection of Q201 and Q202. A divider string R234 and R235 uses the B+ supply to obtain approximately 11.8 volts for pin-5 of V202 while pin-4 is maintained approximately 0 volts through the emitter-base junctions of Q201 and Q202. Any change in the half-wave rectifier voltage causes a corresponding change in the voltage across the emitter-collector junction of Q201 so that the filament and chopper voltage remain stable. The filament supply for V203 is obtained from an ordinary 6.3 volt AC winding.

g. NULL DETECTOR POWER SUPPLY FOR 821A & 821A/AG SERIAL NUMBERS 422 AND ON AND 821AR & 821AR/AG SERIAL NUMBERS 373 AND ON. The +18 volt and -18 volt supply for the null detector is obtained from a center tapped voltage doubler consisting of R229, CR202, CR203, C213, and C214.

h. EFFECT OF AC COMPONENTS. The only AC voltage component that will reduce the accuracy of the 821A is one that either saturates the chopper-amplifier or one that beats with the chopper frequency. Since the voltage required for saturation is greater than that required for beating, the null detector is most sensitive to an AC component with a frequency that is a submultiple or a low multiple of the chopper frequency. However, this is easy to detect because the meter will beat at the difference frequency. The low pass filter at the input of the chopper-amplifier will attenuate any AC component. The magnitude of the AC voltage appearing at the output of the filter depends on both is amplitude and frequency before filtering. For all practical purposes, one should never encounter any trouble above a hundred cycles. Below this, the filter may not attenuate the AC component enough. However, this is not as bad as it appears. A 60 cycle AC voltage that is 1% of the input voltage will cause an error of approximately 0.001% which is well within specifications. If AC components that affect accuracy are ever encountered, additional filtering as set forth in paragraph 2-9 will eliminate the problem.

i. GAIN AND ZERO ADJUSTMENTS. For 821A & 821A/AG serial numbers 123 to 421 and 821AR & 821 AR/AG serial numbers 123 to 372, variable resistor R232 in the null detector power supply provides a means of adjusting the output current of the amplifier to zero when there is no input signal. For later instruments, variable resistor R212 provides a means of adjusting the output current of the amplifier to zero when there is no input signal by utilizing the negative bias voltage on the emitter of Q201 and the positive bias voltage on the emitter of Q205. The gain of the amplifier is adjusted by means of R205 (R222 for 821A & 821A/AG serial numbers 123 to 421 and 821AR & 821AR/AG serial numbers 123 to 372) in the feedback circuit.

j. RECORDER OUTPUT. The recorder output is picked off divider string R224, R1, and R225 (R225, R1, and R226 for 821A & 821A/AG serial numbers 123 to 421 and 821AR & 821AR/AG serial numbers 123 to 372). Output level control R1 provides a means of adjusting the output voltage up to a maximum of at least 18 millivolts at full scale deflection. The voltage at the output terminals is proportional to the meter reading.

3-3. 0 TO 500 VOLT REFERENCE

a. GENERAL. When the 821A is used for differential voltage measurements, an internal voltage is nulled or matched against the unknown voltage. An extremely accurate reference voltage is therefore required. This is obtained from the 0 to 500 volt reference. The 0 to 500 volt reference is composed of a well regulated 500 volt power supply, a range divider, and a Kelvin-Varley five decade attenuator. The output of the 500 volt power supply is applied directly to the Kelvin-Varley attenuator for the 500 volt DC range. In the 50, 5, and 0.5 volt DC ranges, the range divider reduces the voltage to 50, 5, and 0.5 volts before it is applied to the Kelvin-Varley attenuator. The Kelvin-Varley attenuator divides its input voltage (500, 50, 5, or 0.5 volts) into 50,000 equal increments any number of which may be selected by setting the five decades with the voltage readout dials. The output of the Kelvin-Varley attenuator, therefore, provides an extremely accurate reference voltage.

b. 500 VOLT POWER SUPPLY. The 500 volt power supply uses three diodes (CR101, CR102, and CR103) and a filter network (R105, R106, C101, and C102) to supply unregulated DC voltage to series passing tube V102. The voltage is regulated by comparing a sample of the output voltage tapped off a divider string (R119, R120, R121, and R2) with the voltage from reference tube V104 in differential amplifier V105. The output of V105 is fed to differential amplifier V106 which drives the grid of series passing tube V102. The control action of the differential amplifiers continuously adjusts the voltage drop across the series passing tube so as to keep the sample voltage equal to the voltage of the reference tube. Any difference in voltage, the error, is amplified by V105 and V106 and thus changes the voltage drop across V102 to maintain the output at 500 volts.

c. For proper operation a highly stable and accurate balance of amplification must be maintained between the two halves of differential amplifier V105. The filament supply for V105 must be regulated to maintain this balance. A filtered half-wave rectifier (CR104 and C106) drives a Darlington connection of Q101 and Q102. A divider string, R101 and R102, uses the plate of V104 to maintain approximately 6.3 volts on pin-9 of V105 while pin-4 and pin-5 are maintained at approximately 0 volts through the emitter-base junctions of Q101 and Q102. Thus any change in the half-wave rectifier voltage causes a corresponding change in the voltage across the emitter-collector junction of Q101 so that the filament voltage of V105 remains stable.

d. RANGE DIVIDER. In the 500 volt DC range the output of the 500 volt supply is passed directly to the Kelvin-Varley attenuator by range section S2F. In the 50, 5, and 0.5 volt DC positions, range resistors (R320 through R330) selected by section S2E divide the reference voltage to 50, 5, and 0.5 volts before it is switched to the Kelvin-Varley attenuator by section S2F.

e. KELVIN-VARLEY ATTENUATOR. The five Kelvin-Varley decade resistor strings R401 through R455 and associated voltage dials A through E (S6 through S10) provide a means of making the four precision voltages (500, 50, 5, and 0.5) adjustable. Note that each string, with the exception of the first, parallels two resistors of the preceding string. Between the two wipers of S6 (voltage dial A) then, there is a total resistance of 40K (80K paralleled by 80K). With the range switch in the 500 volt position, a total voltage of 100 volts will appear across these two wipers. Also, there will be 10, 1, and 0.1 volts DC across the wipers of S7, S8, and S9, respectively. Voltage dial E (S10) picks increments of 0.01 volt from the last decade. These voltages are reduced by a factor of 10 for each lower voltage range. The Kelvin-Varley resistors are matched for both temperature coefficient and tolerance thus providing an overall attenuator accuracy of 0.002% absolute. With the null switch in any null range, the output of the Kelvin-Varley attenuator is connected in series with the vtvm attenuator thus providing the accurate 0 to 500 volts reference required.

f. ADJUSTMENTS. Variable resistor R121 is used during calibration to set the 500 volt supply to 500 volts with calibrate control R2 set at its center of rotation. This allows the reference supply to be adjusted to 500 volts by means of the calibrate control at any time deemed necessary. With the operate-calibrate switch held at calibrate, a fixed percentage of the 500 volt supply is compared to the precise potential of an internal standard cell or Zener diode (in the /AG models). Any difference in potential is fed to the null detector to give an indication on the meter so that the reference supply can be set with the calibrate control. The fixed percentage of the reference supply is set accurately during calibration by means of R318. The 50, 5, and 0.5 volt range resistor networks are set accurately during calibration by means of R323, R326, and R329.

3-4. POLARITY SWITCH

Because of the polarity switch S5, upper input post J1 should never be electrically connected to the 821A chassis, either at the 821A or at the source under measurement. As seen in figure 3-2, the polarity switch does not reverse the input posts. It reverses the meter and the internal reference supply. If the instrument did not contain a polarity switch, the grounded side of any unknown voltage that is negative with respect to ground would have to be connected to the upper input binding post. This would ground the upper post and effectively place C1 (a 0.47 uf capacitor) across the input terminals. Even if C1 was disconnected, there would still be considerable capacitance across the input due to transformer winding capacitance and stray wiring capacitance. With this capacitance across the circuit being measured several problems would arise. The polarity switch provides equal convenience in measuring positive or negative voltages without the occurrence of these problems.

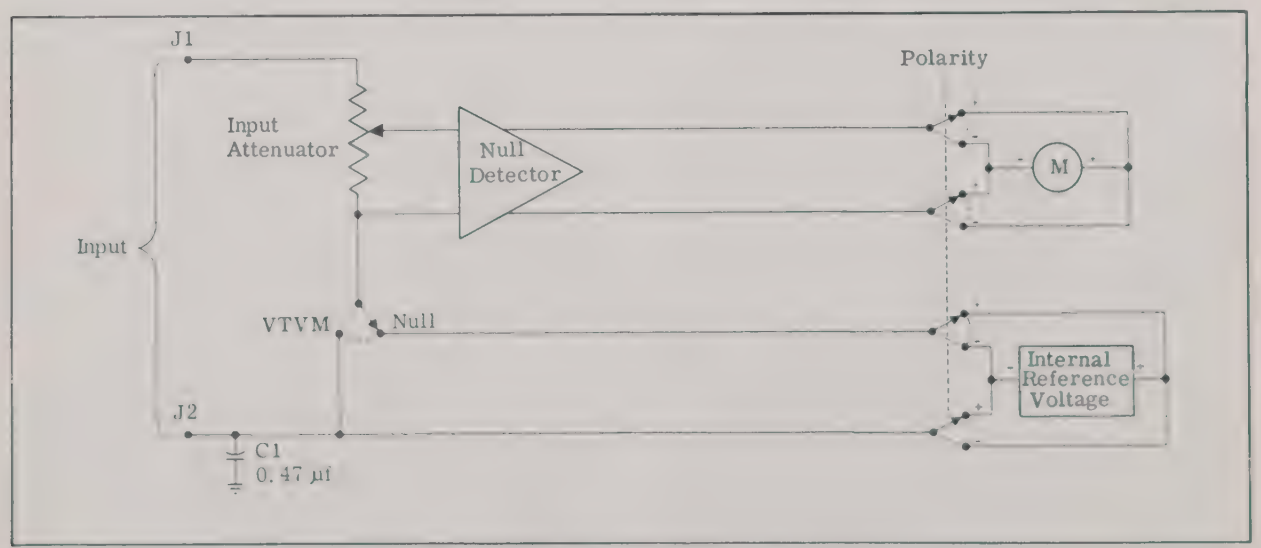


Figure 3-2. FUNCTION OF POLARITY SWITCH

SECTION IV

MAINTENANCE

4-1. GENERAL

The 821A Differential DC Voltmeter seldom requires any maintenance. Without extreme abuse, all that should be required is occasional cleaning, tube replacement, and calibration. Periodic maintenance consists only of preventing any leakage and replacement of the standard cell as discussed in paragraph 4-2. A discussion of troubleshooting along with a troubleshooting chart, component location diagrams, and a tube voltage chart are provided in paragraph 4-3. Paragraph 4-4 delineates the equipment and procedures necessary to calibrate the instrument.

4-2. PREVENTIVE MAINTENANCE

a. LEAKAGE PREVENTION. The accuracy of the 821A is adversely affected by excessive electrical leakage from the input of the null detector to either ground or the 500 volt reference supply. Special care has been taken to prevent leakage across certain critical switch wafers and areas of some printed circuit boards due to moisture from condensation. The printed circuit boards have been coated with Humi-Seal 1B12. The RANGE, NULL, OPERATE-CALIBRATE, and polarity switches have been dipped in Dow Corning silicone oil. Accumulations of dust and foreign matter will cause internal leakage, and should be removed as often as necessary, depending on environmental operating conditions.

b. To check for excessive electrical leakage, proceed as follows:

(1) Perform preliminary operation procedure as stated in paragraph 2-3.

(2) Set switches on 821A as follows:

RANGE	500
NULL	0.1
voltage readout dials	490.00

(3) Remove test leads from input posts.

(4) Excessive leakage is indicated if the meter deflects more than one-tenth of full scale.

c. To prevent excessive electrical leakage, proceed as follows:

(1) Blow the instrument out with low-pressure, clean, dry air to remove most accumulations of dust and foreign matter. Pay particular attention to the binding posts, binding post wiring, critical switches (NULL, RANGE, OPERATE-CALIBRATE, and polarity switches), and for 821A & 821A/AG serial numbers 123 to 421 and 821AR & 821AR/AG serial numbers 123 to 372, the two glass epoxy strips which insulate the chopper-amplifier chassis from the main chassis.

(2) Clean the glass epoxy strips, binding posts, insulators, and front panel with a rag saturated in anhydrous denatured ethyl alcohol.

(3) When necessary, wash all exposed dielectric surfaces of the NULL, RANGE, OPERATE-CALIBRATE, and polarity switches with denatured alcohol using a small, stiff-bristled brush.

CAUTION

Do not use Metriclene, acetone, lacquer thinner, or any other methyl ethyl ketones, since they will react with the Lexan rotor on the CTS plastic switches.

(4) After washing, recoat the exposed switch insulating material with a solution of Dow Corning 200 having a viscosity between 5 and 20 centistokes. This prevents leakage due to moisture on these surfaces.

d. STANDARD CELL REPLACEMENT. As a standard cell ages, its temperature-voltage hysteresis increases. This means that the standard cell voltage takes a longer time to return to its equilibrium value following a temperature change. To be confident of the 0.01% accuracy inherent in the 821A and 821AR, the standard cell should be replaced approximately every four years when the instrument is subjected to temperature changes before measurements are made. However, if the 821A or 821AR is used to make measurements at similar temperatures, the usefull life of the standard cell should far exceed four years.

4-3. CORRECTIVE MAINTENANCE

a. TROUBLESHOOTING. The purpose of troubleshooting is to quickly and accurately determine the cause of any abnormal condition. To assist in localizing most troubles which might occur, the causes and remedies for a number of symptoms are listed in the troubleshooting chart (figure 4-1). Since failure of the 821A is usually due to tube failure, it is recommended that tube substitution be tried before any other tests are made. However, the 821A is conservatively designed and should require very infrequent tube replacement. At certain times, a check of the operating level voltages of the

SYMPTOM	PROBABLE CAUSE	REMEDY
Drift on the 500 volt DC reference supply evidenced by the continual need for resetting with the CALIBRATE control.	V104, V105, or V106 defective.	Check V104, V105, and V106 by replacement.
	One of the sampling string resistors (R119, R120, R121) is changing value rapidly as the instrument warms up.	Locate faulty resistor by heating slightly with a soldering iron held near the resistor while observing the 500 volt DC calibration.
	Drifting standard cell EMF possibly caused by previous inverting of the cell (821A and 821AR only).	Allow time for the standard cell to stabilize. Several hours should be sufficient.
Cannot calibrate 500 volt DC reference supply.	Excessive aging of V104.	Check V104 by replacement.
Meter cannot be brought to zero with CALIBRATE control.	Out of calibration.	Recalibrate per paragraph 4-4.
	One or more resistors in 500 volt DC sampling string has shifted in value.	Recalibrate per paragraph 4-4 and observe stability for 48 hours. If 500 volt DC reference supply remains stable replacement of resistor is unnecessary.
	Standard cell EMF has shifted (821A and 821AR only).	Recalibrate instrument and observe stability of reference supply. Replacement of the standard cell may be necessary.
Measurements are out of tolerance on one range other than the 500 volt range.	A reference supply output range resistor on the range resistor printed circuit board is out of tolerance.	If the trouble occurs in the 50 volt range, R324 has shifted; in the 5 volt range, R327 has shifted; in the 0.5 volt range, R330 has shifted. It may be possible to correct by recalibration. If not, replace faulty resistor.
Measurements are out of tolerance on all ranges other than the 500 volt range.	R320, R321, or R328 has shifted in value.	It may be possible to correct all range voltages by recalibration. If not, replace faulty resistor.
Measurements are out of tolerance on any range when the Kelvin-Varley divider is dialed to any setting other than 499910.	One of the Kelvin-Varley divider resistors is out of tolerance.	Check Kelvin-Varley accuracy per paragraph 4-3e.
Instrument is out of specifications on all ranges.	Resistors R8, R9, R10, R11 or R12 out of tolerance.	Check and replace faulty resistor.
Meter rattle, drift, or error is observed on all null ranges.	V202, V203, or V204 faulty.	Check V202, V203, and V204 by replacement.
	Chopper G1 faulty. (821A, 821A/AG 123 to 421 821AR, 821AR/AG 123 to 372)	Replace chopper
	Moisture or dirt on printed circuit boards or switches.	Clean instrument.

Figure 4-1. TROUBLESHOOTING

tubes (figure 4-2) and transistors (figure 4-3) is also useful. As an aid to troubleshooting, all components may be located by referring to the figures shown in Section V. An understanding of the theory of operation (Section III) and frequent reference to the schematic diagram will be of great value in troubleshooting.

WARNING

Use extreme care when working inside the instrument while it is on. The null detector assembly and all components thereon will be at a voltage close to that indicated by the voltage readout dials.

b. TUBE REPLACEMENT. Many differential amplifier circuits are critical with respect to the balance between halves of differential amplifier tubes. This is especially true of the first stage of amplification. However, the 821A is designed with the ability to use any 12AX7 for V105 and V106 that meets standard EIA (Electronics Industries Association) characteristics. Some output voltage drift of the 500 volt reference supply may be noted for the first few hours of operation. This drift will, in most cases, decrease to a small value after the tube has aged a bit. Occasionally a tube with a contaminated grid or extremely poor balance between halves will be found. This tube should be discarded. When replacing reference tube V104, the new tube should be aged at least 150 hours to realize the high order of stability inherent in the 821A. A tube that has been aged may be obtained by ordering an OG3-2 from Fluke.

c. Replacement of tubes will not normally necessitate complete recalibration of the 821A. If V202 or V203 is replaced for 821A & 821A/AG serial numbers 123 to 421 and 821AR & 821AR/AG serial numbers 123 to 372, calibrate the chopper amplifier as set forth in paragraph 4-4d. Replacement of V102, V104, V105, or V106 will necessitate calibration of the reference supply as stated in paragraph 4-4e.

d. COMPONENT REPLACEMENT. Should it ever become necessary to replace a component on a printed circuit board (or on the null detector chassis for 821A & 821A/AG serial numbers 123 to 421 and 821AR & 821AR/AG serial numbers 123 to 372), proceed as follows:

(1) Clean soldered area around component with Methyl Ethyl Keytone.

(2) Remove part and install new component.

(3) Remove flux with du Pont Freon PC.

(4) Allow to dry for 10 minutes. When it is cool or humid, it may be necessary to place area under a lamp to ensure thorough drying.

(5) For 821A & 821A/AG serial numbers 123 to 421 and 821AR & 821AR/AG serial numbers 123 to 372, coat any uncoated areas around the input to the null detector chassis (tube V202, 5751, and chopper) with Humi-Seal 1B12 (manufactured by Columbia Technical Corp. of Woodside, N. Y.).

(6) If a component at the input to the transistorized null detector (821A & 821A/AG serial numbers 422 and on and 821AR & 821AR/AG serial numbers 373 and on) is replaced, make sure that all leads at the input

Symbol & Type	Pin 1	Pin 2	Pin 3	Pin 4	Pin 5	Pin 6	Pin 7	Pin 8	Pin 9
V102, 6BQ5	No Conn.	495	500 (±3%)	Heater voltage 6.3 volts ac		No Conn.	680 to 730	No Conn.	680 to 730
V104, OG3	85 (±3%)	0	Int. Conn.	0	85 (±3%)	Int. Conn.	0	No Pin	No Pin
V105, 12AX7	217	84	86	Heater voltage 6.0 volts dc		217	84	86	See Pin 4 & 5
V106, 12AX7	495	217	220	Heater voltage 6.3 volts ac		500	217	220	
V202, 5751 (821A, 821A/AG 123 to 421)	60	-	0	Heater voltage 12 volts dc		100	-	1.5	No Conn.
V203, 6AW8 (821AR, 821AR/AG 123 to 372)	47	45	140	Heater voltage 6.3 volts ac		0.7	-	25	50
V204, OA2	150	0	Int. Conn.	0	150	Int. Conn.	0	No Pin	No Pin

This chart is to be used under the following conditions: (a) RANGE switch set to 500; (b) NULL switch set to VTVM; (c) all voltage readout dials set to zero; (d) polarity switch set to +; (e) line voltage at 115/230 volts, 50 - 440 cycles; and (f) all measurements made with a vtvm from negative binding post to specified terminal; (g) all voltages may vary by 20% unless otherwise indicated.

Figure 4-2. TUBE VOLTAGE CHART

TRANSISTOR	Q1	Q2	Q3	Q201	Q202	Q203	Q204	Q205	Q206	Q207
E	3.0	9.3	9.7	-0.45	-0.45	-0.45	0	0.58	-0.54	17.2
B	3.5	9.2	9.3	0	0	0	0.51	0.98	0	16.5
C	9.2	5.8	5.8	0	0	9.2	0.98	7.5	16.5	0

This chart is to be used under the following conditions: (a) voltages for transistors Q201 to Q207 apply to 821A & 821A/AG serial numbers 422 and on and 821AR & 821AR AG serial numbers 373 and on only; (b) RANGE switch set to 500; (c) NULL switch set to VTVM; (d) all voltage readout dials set to zero; (e) polarity switch set to +; (f) line voltage at 115/230 volts, 50-440 cycles; (g) all measurements made with vtvm from negative binding post to specified terminal; and (h) all voltages may vary by 20% unless otherwise indicated.

Figure 4-3. TRANSISTOR VOLTAGE CHART

wire - R201 junction, the R201 - R202 - DS201 - C201 junction, and the R202 - C202 - V201 junction are in physical contact with each other. Otherwise, thermal voltages may result that will degrade the performance of the instrument.

e. KELVIN-VARLEY ACCURACY CHECKING. For this procedure, it is recommended that a six dial Kelvin-Varley divider with a linearity of one part per million and an input capability of 500 volts, a lead compensator, a Fluke Model 301C or 301E Power Supply, and a Fluke Model 825A DC Differential Voltmeter or equivalent be used. To check the accuracy of the Kelvin-Varley divider, proceed as follows:

(1) Disconnect 821A from line power.

(2) On cabinet models, remove screws at back of cabinet and slide instrument out of case.

(3) Remove four screws that hold front panel assembly to chassis and proceed to step (5).

(4) On rack models, remove six screws that hold front panel assembly to chassis.

(5) Being careful to avoid wiring damage, gently lift front panel assembly from instrument and set face down in front of instrument.

(6) Locate high input (wire connected from range switch to S6, usually white-red), high output (wire connected from polarity switch to S10, usually yellow), and input-output common (wire connected from tie point to S6, usually black) of Kelvin-Varley divider.

(7) Connect equipment as shown in Figure 4-4.

(8) Set 821A RANGE switch to 500.

(9) Turn on all equipment and allow it to warmup to equilibrium temperature.

(10) Set power supply for an output of 500 volts DC.

(11) Set 821A voltage readout dials to 00000 and standard divider to 000000.

(12) Set switches on 825A as follows:

RANGE	500
NULL	.001
voltage readout dials	00000
POWER	ON

(13) Adjust lower lead compensator for a null on 825A.

(14) Set 821A voltage readout dials to 499910 and standard divider to 9999$\underline{10}$.

(15) Adjust upper lead compensator for a null on 825A.

(16) Set 825A NULL switch to .01 and change to .001 when more sensitivity is required to take a reading.

(17) Set 821A voltage readout dials and standard divider to positions shown in Figure 4-5. The 825A null detector indication should be equal to or less than the listed deviation. If Kelvin-Varley divider is out of tolerance between settings of 499910 and 099910, recalibrate as set forth in paragraph 4-4g and then recheck. If a resistor-trimmer combination of the first deck can not be adjusted for a null during calibration, the 39,996 ohm resistor is defective and must be replaced. If Kelvin-Varley divider is out of tolerance for remaining settings, replace defective resistor. All resistors of each decade are matched and the decades are matched for each instrument. When ordering a Kelvin-Varley resistor, the instrument model and serial number as marked on the name plate and all the information stamped on the resistor must be supplied to Fluke. This ensures that a resistor compatible with the matched resistor group within the instrument is used. The Kelvin-Varley resistors are very stable and precise, resistance is clearly defined, therefore; they must be handled with care. This is especially true of the varnished-dipped-card resistors.

CAUTION

Pick up card resistors between ends of card. Never touch the wire on the cards as damage to the resistor could possibly result.

If it becomes necessary to replace a resistor in the first deck (R401 to R406 or R450 to R455), recalibrate the Kelvin-Varley divider as set forth in paragraph 4-4g.

f. STANDARD CELL PROBLEMS. The standard cell of the 821A and 821AR deserves special consideration if it is suspected of being faulty:

(1) The standard cell used is a miniature unsaturated

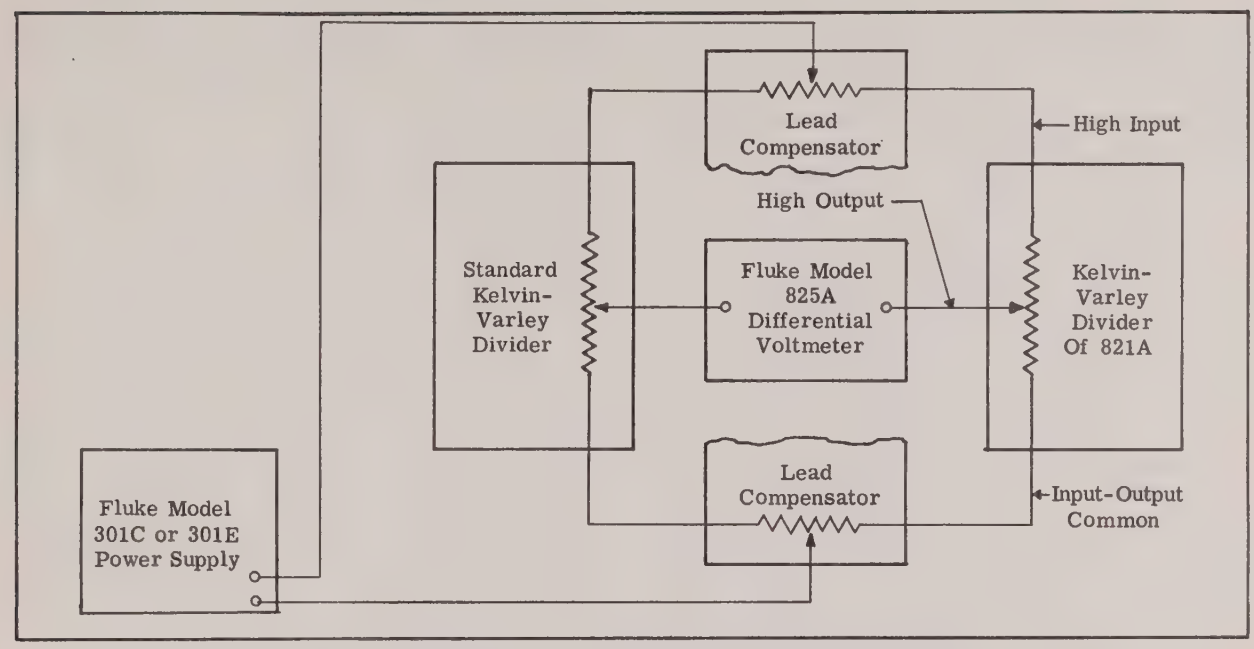


Figure 4-4. KELVIN-VARLEY DIVIDER CHECKING SETUP

821A Voltage Dial Settings	Standard Divider Settings	Maximum Deviation (± millivolts)
499910	.9999910	0
40000	.800000	8.0
399910	.800000	8.0
30000	.600000	6.0
299910	.600000	6.0
20000	.400000	4.0
199910	.400000	4.0
10000	.200000	2.0
099910	.200000	2.0
09000	.180000	1.8
089910	.180000	1.8
08000	.160000	1.6
079910	.160000	1.6
07000	.140000	1.4
069910	.140000	1.4
06000	.120000	1.2
059910	.120000	1.2
05000	.100000	1.0
049910	.100000	1.0
04000	.080000	1.0
039910	.080000	1.0
03000	.060000	.8
029910	.060000	.8
02000	.040000	.8
019910	.040000	.8
01000	.020000	.6
009910	.020000	.6
00900	.018000	.6
008910	.018000	.6
00800	.016000	.6
007910	.016000	.6
00700	.014000	.6

821A Voltage Dial Settings	Standard Divider Settings	Maximum Deviation (± millivolts)
006910	.014000	.6
00600	.012000	
005910	.012000	
00500	.010000	
004910	.010000	
00400	.008000	
003910	.008000	
00300	.006000	
002910	.006000	.6
00200	.004000	.4
001910	.004000	
00100	.002000	
000910	.002000	
00081̄0	.001800	
00071̄0	.001600	
00061̄0	.001400	
00051̄0	.001200	
00041̄0	.001000	
00031̄0	.000800	.4
00021̄0	.000600	.3
00011̄0	.000400	
00001̄0	.000200	
00009	.000180	
00008	.000160	
00007	.000140	
00006	.000120	
00005	.000100	
00004	.000080	
00003	.000060	
00002	.000040	
00001	.000020	.3
00000	.000000	.0

Figure 4-5. KELVIN-VARLEY ERROR LIMITS

cell which has excellent long term stability and negligible temperature-voltage hysteresis. (Temperature-voltage hysteresis is the erratic behavior of the voltage while the cell is coming to equilibrium following a change in temperature.) With time, however, the temperature-voltage hysteresis increases. The 821A uses the latest type of cells which have a useful life that should exceed 5 years under normal operating conditions, storage and operating temperatures between 68°F and 86°F.

(2) Failure of the standard cell may occur if subjected to below freezing temperature. The electrolyte will start to freeze at about 5°F and operation below 32°F is definitely not recommended. If temperatures below -10°F are encountered for more than 4 hours, it is recommended that the standard cell be replaced. The life of the cell will also be shorter if the cell is operated at elevated temperatures. For approximately every 22°F rise in temperature above 73°F, the aging rate is doubled. For example, the cell will typically decrease in voltage by 20 ppm/yr at 73°F, 40 ppm/yr at 95°F, and 80 ppm/yr at 117°F.

(3) The emf of different cells may vary as much as 0.05% and each instrument is calibrated to its own particular standard cell. Thus, when the standard cell is replaced, the 821A reference supply must be recalibrated as in paragraph 4-4e (3).

(4) The emf of the standard cell will change if the cell has been inadvertently short circuited. If the emf of the cell has changed, the 821A will naturally be out of calibration on all ranges. However, if the cell has been shorted for only a few seconds, the cell will recover enough within 10 minutes to make measurements within specifications. Also, if the cell has been inverted for a few days, the voltage will recover enough to make measurements within specifications immediately upon being restored to an upright position.

g. DECIMAL LAMP REPLACEMENT. The decimal lamps are normal 6.3 volt pilot bulbs. To prolong their life these bulbs are operated from a 5 volt transformer winding. However, these bulbs do occasionally fail. To replace, proceed as follows:

(1) On cabinet models, remove screws at back of cabinet and slide instrument out of case. If only the upper most decimal lamp needs to be replaced, proceed to step (6).

(2) Remove four screws that hold front panel assembly to chassis.

(3) Being careful to avoid wiring damage, gently lift front panel assembly from instrument and set face down in front of instrument.

(4) Remove screws holding range resistor printed to front panel assembly.

(5) Push printed circuit board aside enough to allow access to light holders.

(6) Remove pilot light holder from bracket by applying pressure to each side of holder.

(7) Remove cardboard light shield and replace pilot light.

(8) On rack models, remove screws holding cover to instrument and set cover aside.

(9) Remove pilot light holder from bracket by applying pressure to each side of holder.

(10) Remove cardboard light shield and replace pilot light.

h. CHOPPER DRIVE FREQUENCY ADJUSTMENT FOR 821A & 821A/AG SERIAL NUMBERS 123 TO 421 AND 821AR & 821AR/AG SERIAL NUMBERS 123 TO 372. If it ever becomes necessary to replace one or more of the chopper drive unit transistors (Q701 through Q704), the frequency and symmetry of the output must be reset. Proceed as follows:

(1) After replacing transistors, connect an oscilloscope between the emitter of Q703 and lower input post (middle post) to observe the output waveform.

(2) Adjust R704 until output is within ±3% of symmetry.

(3) Adjust R705 for a frequency of 83 cycles ±2%.

i. CHOPPER DRIVE FREQUENCY ADJUSTMENT FOR 821A & 821A/AG SERIAL NUMBERS 422 & ON AND 821AR & 821AR/AG SERIAL NUMBERS 373 & ON. The chopper drive frequency needs to be adjusted only a few times during the life of the instrument. As neon lamps DS202 and DS203 age, their voltage will change slightly and cause the frequency to shift. This is especially true during the early life of the instrument. However, the chopper drive frequency needs to be adjusted only if a beating effect appears on the meter due to line frequency interference. Proceed as follows:

(1) Set controls on voltmeter as follows:

POLARITY	+ (positive)
NULL	.001
all voltage readout dials	0 (zero)

(2) Connect an oscillator to input of voltmeter through a capacitor of about 0.1 microfarads.

(3) Set oscillator for an output of 84 cycles.

(4) Adjust R226 until meter begins to beat and then adjust for zero beat.

4-4. CALIBRATION

a. GENERAL. The 821A should be calibrated as often as deemed necessary. However, it is recommended that the instrument be calibrated every six months for standard cell models and three months for zener diode models under ordinary laboratory conditions. For special applications where extreme accuracy is required, it may be desired to calibrate the instrument more frequently. If subjected to a temperature greater than 130°F or less than 10°F, the instrument should be recalibrated; but, it should be recalibrated no sooner than 24 hours after being removed from the extreme temperature environment. If the instrument is subjected to a temperature of less than -10°F for more than 4 hours, it is recommended that the standard cell be replaced. Calibration should be accomplished under typical laboratory operating conditions in a draft free area with ambient temperature of 72(±3)°F for a maximum accuracy. The instrument should be calibrated in its case.

b. For convenience, the calibration procedure is divided into four parts: Preliminary Calibration, Null Detector Calibration, Reference Supply Calibration, and Range Divider Calibration. Calibration is normally done by performing all four parts in the sequence given here. However, the calibration procedure is written

so that any section of the 821A may be calibrated by just performing the calibration procedure for that section. The recommended equipment and the specifications required for calibration are shown in figure 4-6. All controls may be located with the aid of figure 4-7.

RECOMMENDED EQUIPMENT	SPECIFICATIONS REQUIRED
Fluke 301C or 301E Power Supply Saturated standard cell bank with an accuracy of ±0.001% Voltage reference divider having division ratios of 1, 10, 100, and 1000, with an accuracy of ±0.001% Galvanometer suitable for use with above voltage reference divider	The equipment used must provide 500, 50, 5, and 0.5 volts with an accuracy of ±0.002%

Figure 4-6. CALIBRATION EQUIPMENT

c. PRELIMINARY CALIBRATION PROCEDURES

(1) Set 821A meter to zero with mechanical zero control.

(2) Set switches on 821A as follows:

RANGE	500
NULL	VTVM
polarity	+ (positive)
all voltage readout dials	0 (zero)

(3) Set power switch to ON and allow 821A to warmup to equilibrium temperature (about 1/2 hour).

(4) Set up necessary equipment to provide DC voltages of 500, 50, 5, and 0.5 volts with an accuracy of 0.002%. Proceed as follows: turn on all test equipment and allow it to warmup to equilibrium temperature (about 1/2 hour); set proper standard cell voltage on divider, apply 500 volts DC into divider from power supply; set divider to 500 and zero galvanometer by varying output of power supply; voltages of 500, 50, 5, and 0.5 volts DC (±0.002%) are made available at output posts by merely changing position of voltage selector switch on voltage divider.

(5) Connect chassis ground binding post to line ground.

(6) Use an insulated screwdriver to reach controls through ventilation holes in cabinet. This must be done to prevent shorting control to chassis ground.

d. NULL DETECTOR CALIBRATION

(1) Perform preliminary calibration procedure as stated in paragraph 4-4c.

(2) Adjust VTVM ZERO ADJ control R212 (R232 for 821A & 821A/AG serial numbers 123 to 421 and 821AR & 821AR/AG serial numbers 123 to 372) until 821A meter indicates zero.

(3) Apply 500 VDC (±0.002%) to voltmeter.

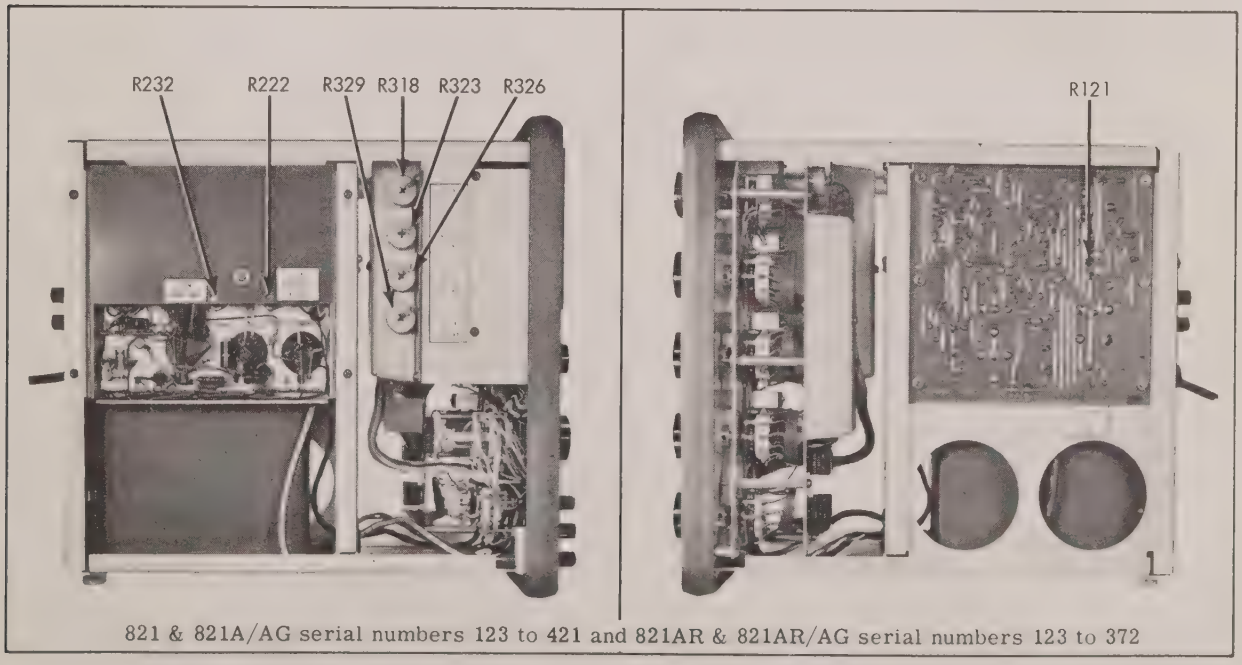
(4) Adjust VTVM GAIN ADJ control R205 (R222 for 821A & 821A/AG serial numbers 123 to 421 and 821AR & 821AR/AG serial numbers 123 to 372) for full scale deflection.

e. 500 VDC REFERENCE SUPPLY CALIBRATION

(1) Perform preliminary calibration procedure as stated in paragraph 4-4c.

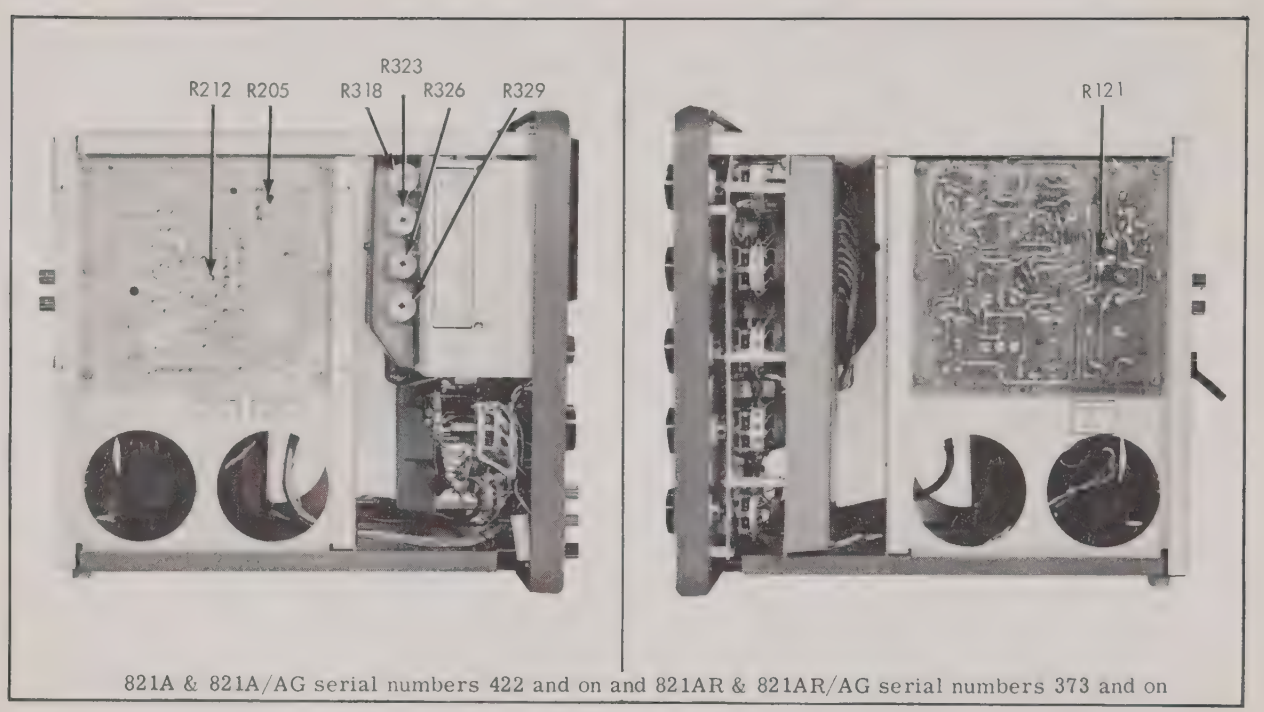
(2) Center CALIBRATE control at its center of rotation.

(3) Set switches on 821A as follows:



821 & 821A/AG serial numbers 123 to 421 and 821AR & 821AR/AG serial numbers 123 to 372

Figure 4-7. ADJUSTMENT LOCATIONS (sheet 1 of 2)



821A & 821A/AG serial numbers 422 and on and 821AR & 821AR/AG serial numbers 373 and on

Figure 4-7. ADJUSTMENT LOCATIONS (sheet 2 of 2)

RANGE	500
NULL	10
voltage readout dials	499.910

(4) Apply 500 VDC (±0.002%) to voltmeter.
(5) Adjust 500 V REF ADJ control R121 for a null.
(6) Set NULL switch to 0.1 volt.
(7) Null 821A meter by adjusting CALIBRATE control.
(8) Advance OPERATE-CALIBRATE switch against spring tension to CALIBRATE and null meter by adjusting REF CAL ADJ control R318.

f. RANGE DIVIDER CALIBRATION

(1) Perform preliminary calibration procedure as stated in paragraph 4-4c.
(2) Set switches on 821A as follows:

RANGE	50
NULL	0.01
voltage readout dials	49.9910

(3) Apply 50 VDC (±0.002%) to voltmeter.
(4) Null 821A meter by adjusting 50V ADJ control R323.
(5) Set RANGE switch to 5 volts.
(6) Apply 5 VDC (±0.002%) to voltmeter.
(7) Null 821A meter by adjusting 5V ADJ control R326.
(8) Set RANGE switch to 0.5 volts.
(9) Apply 0.5 VDC (±0.002%) to voltmeter.
(10) Null 821A meter by adjusting 0.5V ADJ control R329.

g. KELVIN-VARLEY CALIBRATION. The 821A Kelvin-Varley divider should be calibrated only after a resistor (R401 to R406 or R450 to R455) of the first deck has been replaced or after the Kelvin-Varley divider checking procedure (paragraph 4-3e) indicates that the Kelvin-Varley divider is out of tolerance. For this procedure, it is recommended that a six dial Kelvin-Varley divider with a linearity of one part per million, a Leeds and Northrup Model 9834 Galvanometer, and a Fluke Model 301C or 301E power supply be used. Proceed as follows:

(1) Disconnect 821A from line power.
(2) On cabinet models, remove screws at back of cabinet and slide instrument out of case.
(3) Remove four screws that hold front panel assembly to chassis and proceed to step (5).
(4) On rack models, remove six screws that hold front panel assembly to chassis.
(5) Being careful to avoid wiring damage, gently lift front panel assembly from instrument and set face down in front of instrument.
(6) Remove screws holding Kelvin-Varley board to front panel assembly and push board aside enough to allow access to Kelvin-Varley switches.
(7) Locate wires (usually white-black and white-brown) that connect second deck of Kelvin-Varley divider to first deck (wires are connected from S7 to S6 as shown in figure 5-2) and unsolder at S6.
(8) Connect equipment as shown in figure 4-8. The 80K resistance shown is total resistance of second through fifth deck which exists between wires unsoldered in step (7). The series connection of 39,996 ohm resistor and 10 ohm trimmer is one of six resistor-trimmer sets. Use each set, one at a time, by connecting at switch S6 to adjacent wires (usually blue) coming from Kelvin-Varley board.
(9) Turn all equipment on and allow it to warmup to equilibrium temperature (about 1/2 hour).

(10) Set power supply for an output of 100 volts DC.
(11) Set standard Kelvin-Varley divider to . 666667.
(12) Adjust 10 ohm trimmer resistor for a null on galvanometer.

(13) Repeat with next resistor-trimmer combination of the first deck until all six trimmer resistors (R450 to R455) have been adjusted.
(14) Check accuracy of Kelvin-Varley divider using procedure of paragraph 4-3e.

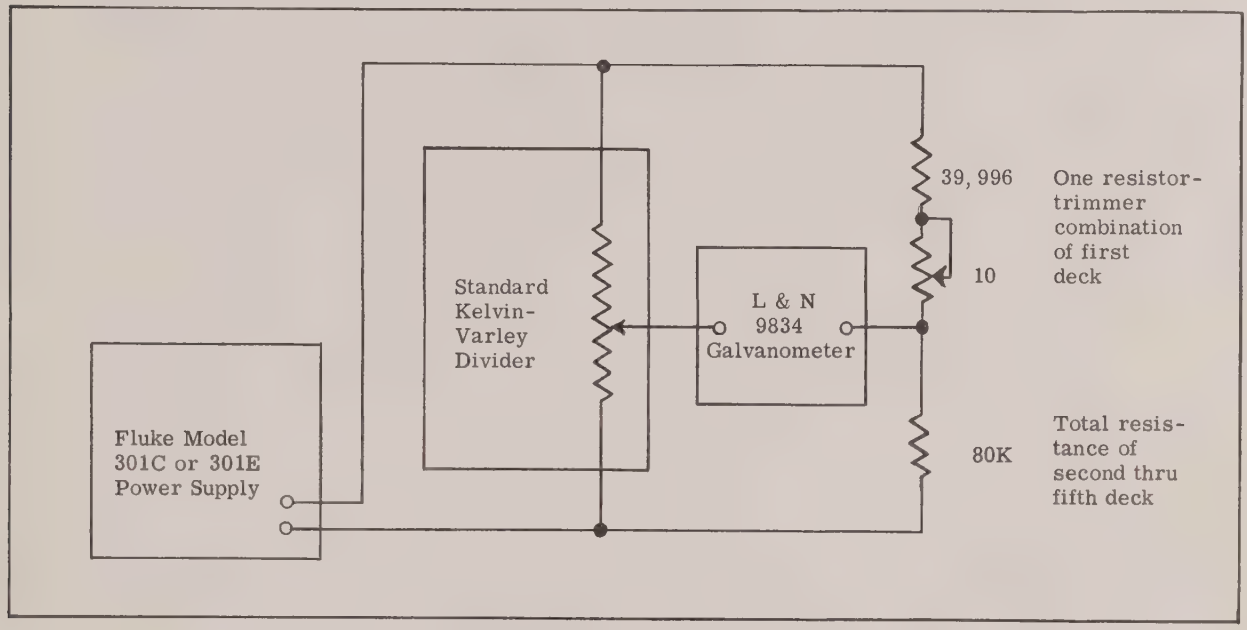

39, 996
One resistor-trimmer combination of first deck
10
Standard Kelvin-Varley Divider
L & N 9834 Galvanometer
Fluke Model 301C or 301E Power Supply
80K
Total resistance of second thru fifth deck

Figure 4-8. KELVIN-VARLEY DIVIDER CALIBRATION

SECTION V

LIST OF REPLACEABLE PARTS

5-1 GENERAL

a. The following seven assembly lists describe all normally replaceable parts of the Model 821A, 821AR, 821A/AG, and 821AR/AG Differential DC Voltmeters. Each list has a corresponding illustration on which the parts for that list are pointed out. Parts are called out on both lists and illustrations by reference designations from the schematic diagram. Those parts (mechanical) which have no reference designation are shown on the illustrations by Fluke stock number.

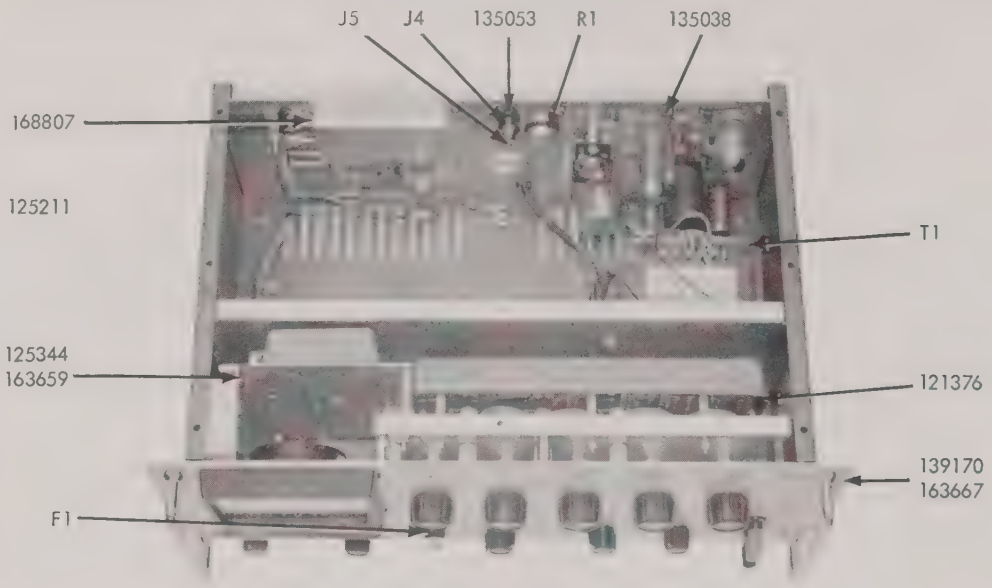
b. A Use Code column is provided to identify certain parts that have been added, deleted, or modified during production of the 821A. Each part for which a use code has been assigned may be identified with a particular instrument serial number by consulting the Use Code Effectivity List at the end of this section.

5-2. HOW TO OBTAIN PARTS

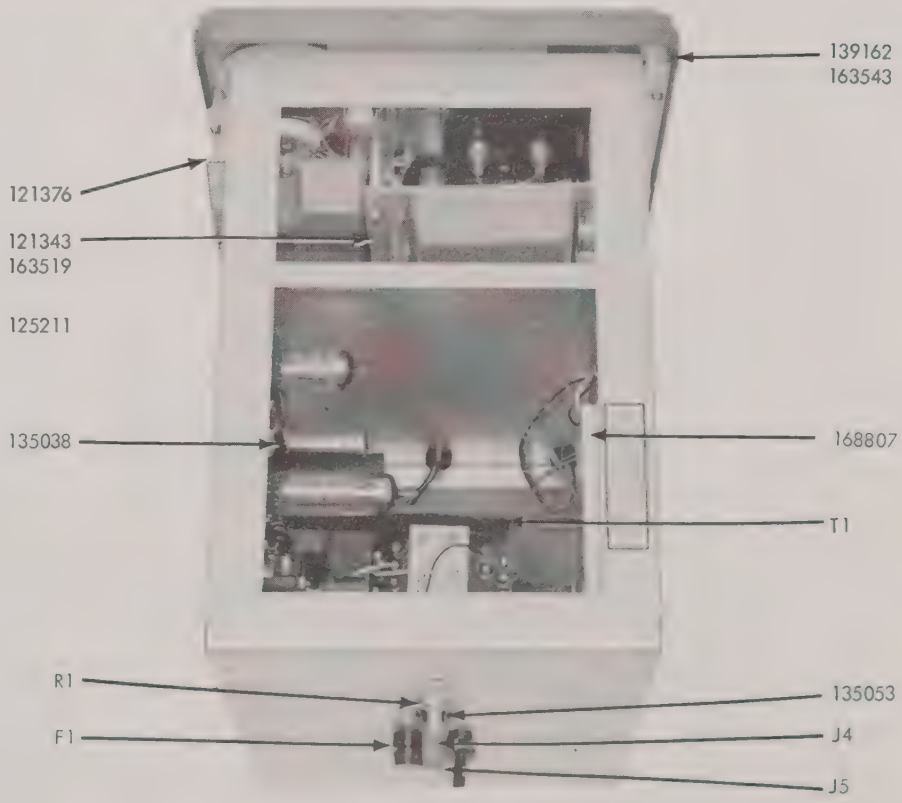
a. Standard components have been used whenever possible. Thus, most parts may be obtained locally. However, special components are used in some instances. All parts manufactured or altered by Fluke and all parts for which Fluke controls the design are designated by an (*) asterisk preceding the Fluke stock number. All structural parts and special parts should be purchased from your local Fluke representative or from the factory.

b. When ordering parts always include:
(1) Reference designation, description, and Fluke stock number.
(2) Instrument model and serial number.
(3) Most structural parts are not listed. In this case, give complete description, function, and location for the part.

REFERENCE DESIGNATION	DESCRIPTION	FLUKE STOCK NO.	USE CODE
	Final Assembly (Cabinet model, standard cell option)	*821A	
	(Rack model, standard cell option)	*821AR	
	(Cabinet model, Zener diode option)	*821A/AG	
	(Rack model, Zener diode option)	*821AR/AG	
	Front Panel Assembly (See figure 5-2) (821A)	*139162	
	(821AR)	*139170	
	(821A/AG)	*163543	
	(821AR/AG)	*163667	
	Reference Supply Board Assembly (See figure 5-3)	*135038	
	Null Detector Chassis Assembly (See figure 5-4)	*125229	I
		*168807	J
	Range Resistor Board Assembly (See figure 5-5)(821A)	*121343	
	(821AR)	*125344	
	(821A/AG)	*163519	
	(821AR/AG)	*163659	
	Kelvin-Varley Resistor Board Assembly (See figure 5-6)	*121376	
	Chopper Drive Board Assembly (See figure 5-7)	*125211	I
F1	Fuse, 1 ampere, slow blowing (for 115 volt operation)	109272	
	Fuse, 1/2 ampere, slow blowing (for 230 volt operation)	109322	
	Fuse holder	100107	
J4, J5	Binding post, red	104158	
	Binding post insulator, dual, black	*135053	
R1	Resistor, variable wirewound, 10K ±10%, 2W	111617	
T1	Transformer, power	*121418	I
		*161216	J
	Line cord, 3 wire	102822	
	Rubber foot	101253	
	Case Assembly (Cabinet model)	*134858	
	Handle, flexible black vinyl, 5-1/2" (Cabinet model)	407-101	



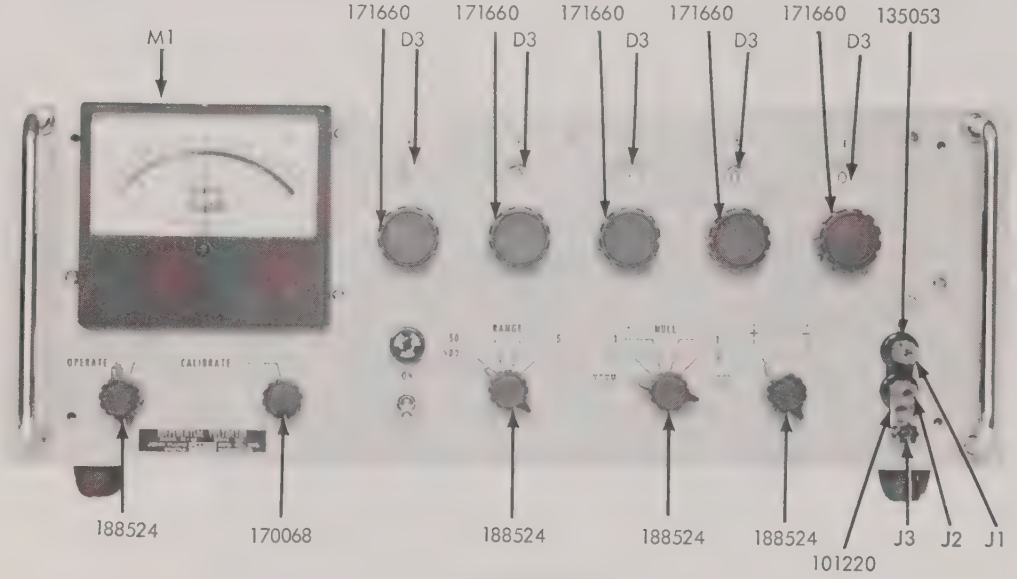
RACK MODEL



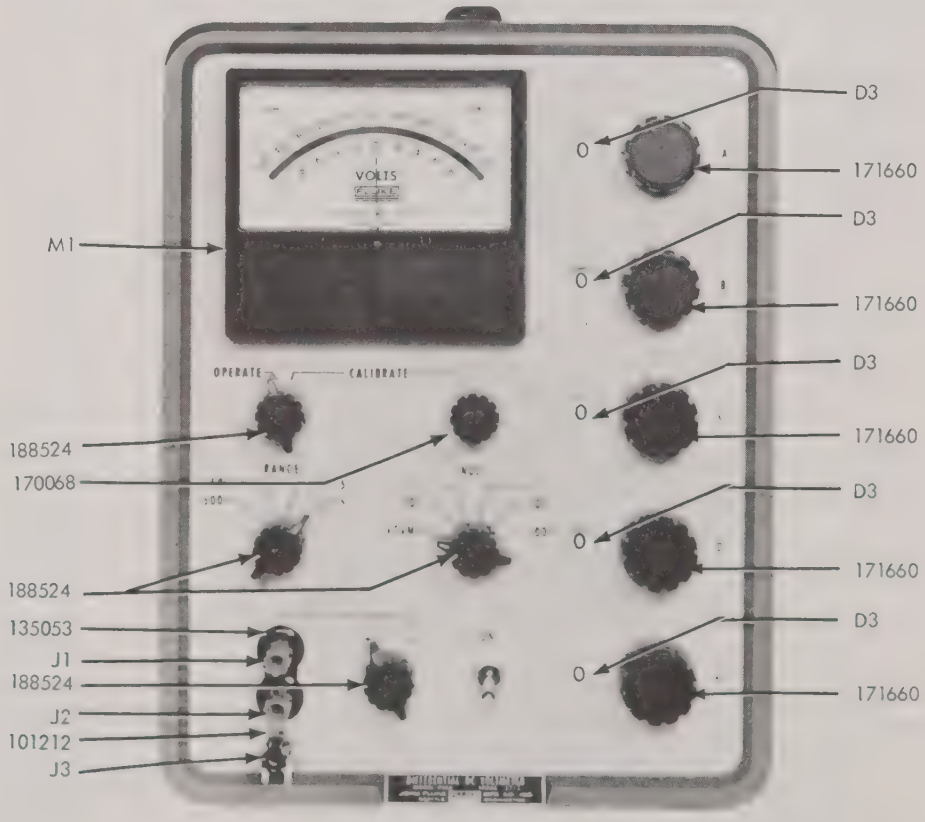
CABINET MODEL

Figure 5-1. FINAL ASSEMBLY

REFERENCE DESIGNATION	DESCRIPTION	FLUKE STOCK NO.	USE CODE
	Front Panel Assembly (821A)	*139162	
	(821AR)	*139170	
	(821A/AG)	*163543	
	(821AR/AG)	*163667	
B1	Standard Cell (821A and 821AR)	135160	
C1	Capacitor, plastic, 0.47 uf ±10%, 600V	105494	
DS1, DS2, DS3, DS4	Lamp, decimal	102855	
	Light holder	100131	
	Light shield	101428	
	Light lens	103440	
J1, J2	Binding post, red	104158	
	Binding post, insulator, dual, black	*135053	
	Shorting link	101220	
J3	Binding post, black	101204	
	Binding post, spacer	101212	
M1	Meter, 100-0-100 microamp	*111211	
R2	Resistor, variable wirewound, dual section, 1K and 100Ω ±10%, 2W	112714	
R3 thru R6	Resistor, carbon film, 10 Meg ±1%, 1W	107748	
R7	Resistor, carbon film, 9 Meg ±1%, 1W	107557	
R8	Resistor, carbon film, 900K ±1%, 1/2W	107391	
R9	Resistor, carbon film, 90K ±1%, 1/2W	107292	
R10	Resistor, carbon film 9K ±1%, 1/2W	107250	
R11	Resistor, carbon film, 900Ω ±1%, 1/2W	107771	
R12	Resistor, carbon film, 100Ω ±1%, 1/2W	107730	
S1	Switch, power	114850	
S2	Switch, range	*125138	
S3	Switch, null	*121483	
S4	Switch, operate-calibrate	*134973	
S5	Switch, polarity	*121475	
S6	Switch, voltage dial A	*134817	
S7, S8, S9	Switch, voltage dials B, C, and D	*134841	
S10	Switch, voltage dial E	*134825	
	Knob	101287	G
		188524	H
		170068	H
	Knob	101121	G
		171660	H
	Knob	101311	G
		188524	H
	Voltage dial plates (Cabinet model)	107029	
	(Rack model)	107011	
	Handle, 6" chrome plated (Rack model)	101717	

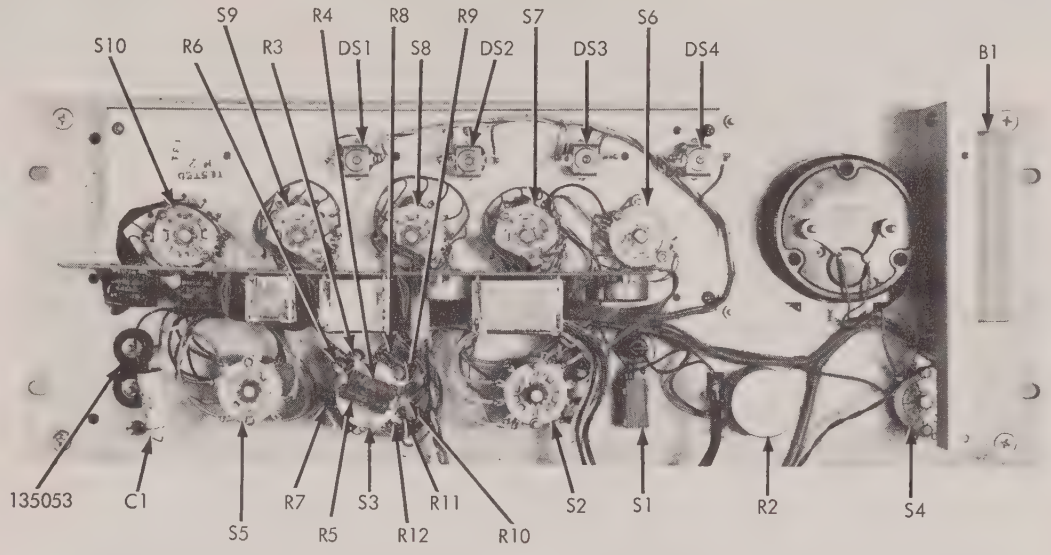


RACK MODEL



CABINET MODEL

Figure 5-2. FRONT PANEL ASSEMBLY. (Sheet 1 of 2)



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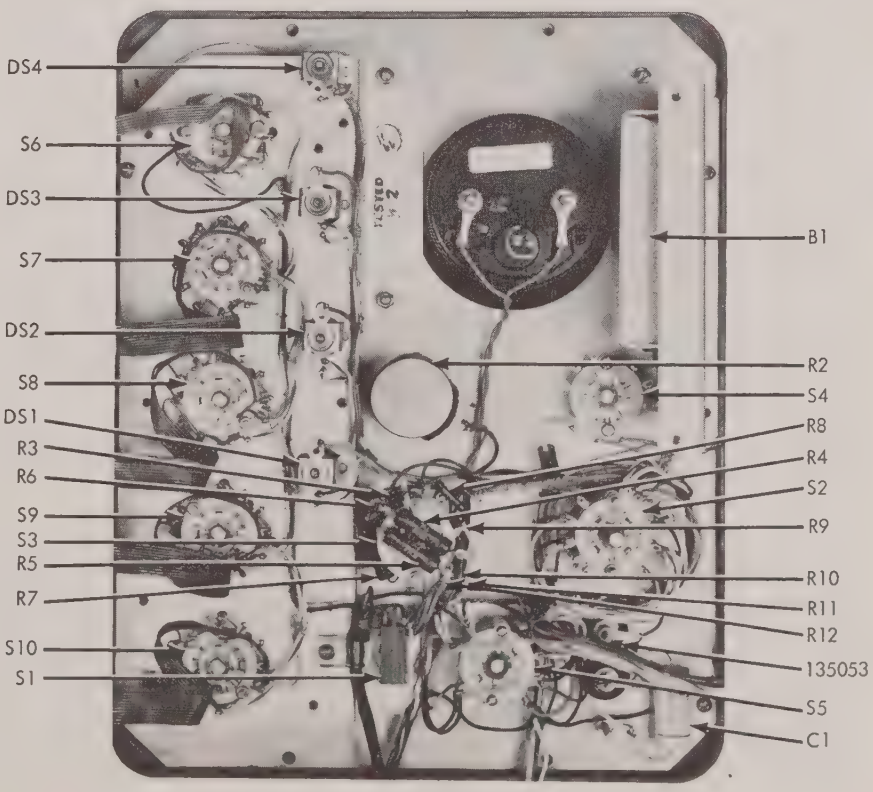

CABINET MODEL

Figure 5-2. FRONT PANEL ASSEMBLY. (Sheet 2 of 2)

REFERENCE DESIGNATION	DESCRIPTION	FLUKE STOCK NO.	USE CODE
	Reference Supply Board Assembly without tubes	*135038	
C101, C102	Capacitor, electrolytic, 20 uf -10/+100%, 500V	105932	
C103	Capacitor, paper, 0.1 uf ±20%, 400V	105312	
C104	Capacitor, plastic, 0.033 uf ±20%, 600V	105916	
C105	Capacitor, plastic, 0.1 uf ±20%, 600V	105833	
C106	Capacitor, electrolytic, 1500 uf -10/+150%, 16V	106666	
CR101 thru CR104	Diode, silicon, 0.750 Amp, 600 PIV Diode, silicon, 0.750 Amp, 600 PIV	112680 112383	C D
Q101	Transistor, germanium PNP	*116707	
Q102	Transistor, germanium PNP, 2N1372	116129	
R101	Resistor, carbon film, 5K ±1%, 1/2W	107110	
R102	Resistor, carbon film, 62K ±1%, 1/2W	107722	
R103	Resistor, composition, 1 Meg ±10%, 1/2W	108134	
R104	Resistor, composition, 220K ±10%, 1/2W	108217	
R105, R106	Resistor, composition, 270K ±10%, 1W	109512	
R107	Resistor, composition, 22 Meg ±10%, 1/2W	108233	
R108	Resistor, composition, 15 Meg ±10%, 1/2W	108647	
R109	Resistor, composition, 10 Meg ±10%, 1/2W	108142	
R110	Resistor, composition, 100K ±10%, 1W	109397	
R111	Resistor, wirewound, 140K ±3%, 10W	112417	
R112	Resistor, composition, 100K ±10%, 1/2W	108126	
R113	Resistor, composition, 560K ±10%, 1W	109678	
R114	Resistor, composition, 220K ±10%, 1/2W	108217	
R115	Resistor, composition, 330Ω ±10%, 1/2W	108589	
R116	Resistor, composition, 220K ±10%, 1W	109652	
R117	Resistor, composition, 82K ±10%, 1/2W	108498	
R118	Resistor, composition, 560K ±10%, 1W	109678	
R119	Resistor, wirewound, 386K ±0.5%, 1W	112482	
R120	Resistor, wirewound, 76K ±0.5%, 1/2W	111948	
R121	Resistor, variable wirewound, 5K ±20%, 1-1/4W	111609	

REFERENCE DESIGNATION	DESCRIPTION	FLUKE STOCK NO.	USE CODE
V102	Vacuum tube, pentode, EL84/6BQ5	116616	
V103	Lamp, neon glow, NE2E (For replacement, use 170167) Lamp, neon glow, NE83	100347 170167	E F
V104	Vacuum tube, voltage reference, aged OG3	*116749	
V105, V106	Vacuum tube, duo triode, 12AX7	115956	

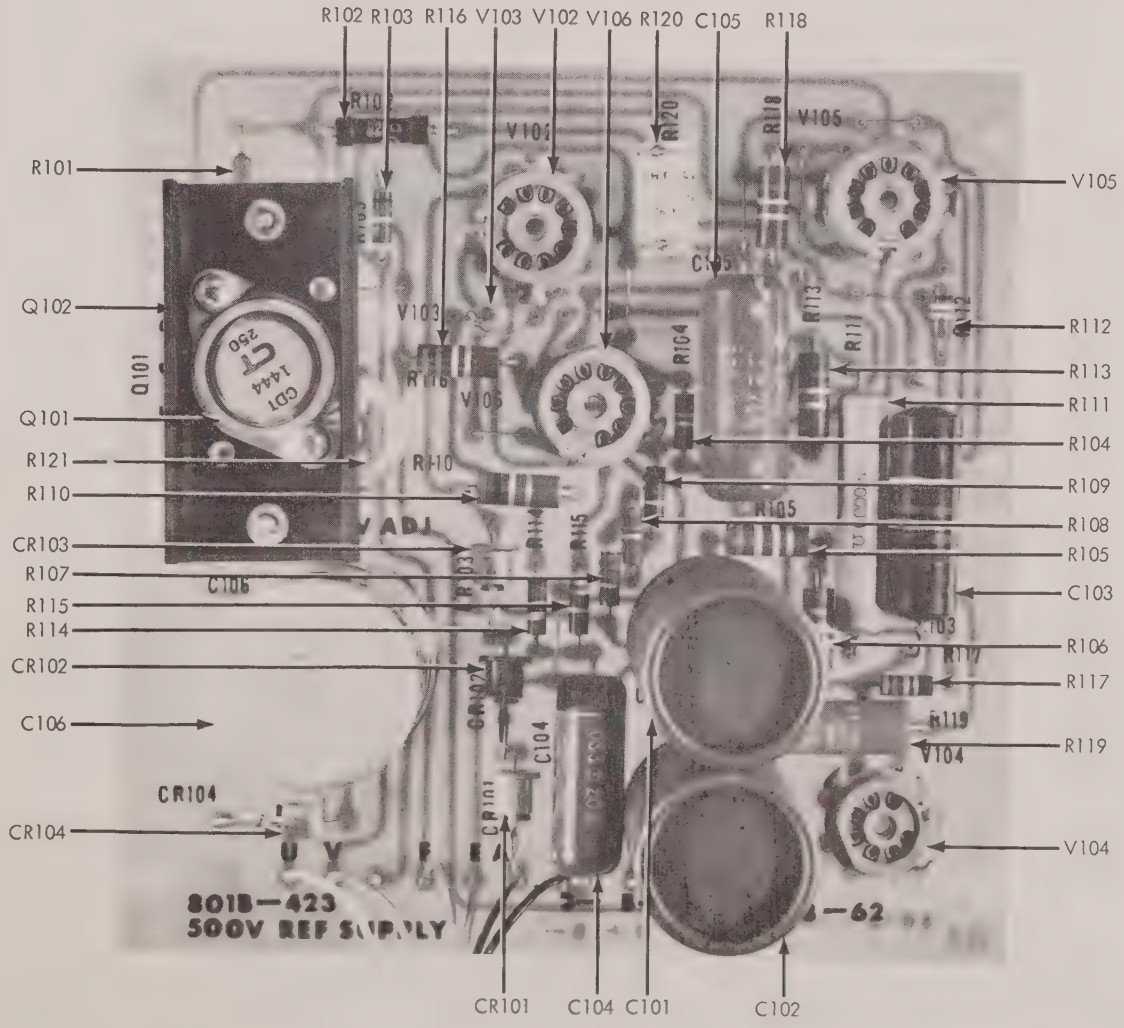

Figure 5-3. REFERENCE SUPPLY BOARD ASSEMBLY

REFERENCE DESIGNATION	DESCRIPTION	FLUKE STOCK NO.	USE CODE
	NOTE: This assembly applies to 821A & 821A/AG serial numbers 123 to 421 and 821AR & 821AR/AG serial numbers 123 to 372.		
	Null Detector Chassis Assembly without tubes	*125229	
C201, C202	Capacitor, plastic, 0.1 uf ±20%, 100V	106526	
C203	Capacitor, paper, 0.047 uf ±20%, 400V	105718	
C204 ABC	Capacitor, electrolytic, 40-20-20 uf -10/+100%, 250V	106542	
C205	Capacitor, plastic, 0.1 uf ±20%, 200V Capacitor, plastic, 0.1 uf ±20%, 200V	106310 106435	A B
C206	Capacitor, electrolytic, 100 uf -10/+100%, 3V	106534	
C207	Capacitor, ceramic, 0.005 uf ±20%, 500V	105650	
C208	Capacitor, plastic, 0.1 uf ±20%, 200V Capacitor, plastic, 0.1 uf ±20%, 200V	106310 106435	A B
C209	Capacitor, plastic, 0.47 uf ±20%, 200V	106419	
C210	Capacitor, plastic, 0.1 uf ±20%, 200V Capacitor, plastic, 0.1 uf ±20%, 200V	106310 106435	A B
C211	Capacitor, electrolytic, 5 uf -10/+100%, 50V	106500	
C212	Capacitor, electrolytic, 500 uf -10/+100%, 3V	106328	
C213 AB	Capacitor, electrolytic, 20-20 uf -10/+50%, 450V	105064	
C214	Capacitor, electrolytic, 2000 uf -10/+100%, 25V	105171	
C215	Capacitor, electrolytic, 30 uf -10/+100%, 15V	106492	
C216	Capacitor, electrolytic, 15 uf -10/+150%, 6V	105700	
CR201	Diode, silicon, 0.75 Amp, 600 PIV Diode, silicon, 0.75 Amp, 600 PIV	112680 112383	C D
CR202	Diode, silicon, 1 Amp, 100 PIV	116111	
CR203	Diode, silicon, 0.75 Amp, 600 PIV Diode, silicon, 0.75 Amp, 600 PIV	112680 112383	C D
CR204, CR205	Diode, silicon, 1 Amp, 100 PIV	116111	
G1	Chopper, electromechanical, SPDT	104455	
Q201	Transistor, germanium PNP, special purpose 2N301W	*116707	
Q202	Transistor, germanium PNP, 2N1372	116129	
R201 thru R203	Resistor, composition, 820K ±10%, 1/2W	108357	
R204	Resistor, composition, 2.2 Meg ±10%, 1/2W	108225	
R205	Resistor, composition, 22K ±10%, 1/2W	108209	
R206	Resistor, composition, 150K ±10%, 1/2W	108167	

REFERENCE DESIGNATION	DESCRIPTION	FLUKE STOCK NO.	USE CODE
R207	Resistor, composition, 4.7K ±10%, 1/2W	108381	
R208	Resistor, composition, 10 Meg ±10%, 1/2W	108142	
R209	Resistor, composition, 10K ±10%, 1/2W	108118	
R210	Resistor, composition, 220K ±10%, 1/2W	108217	
R211, R212	Resistor, composition, 1 Meg ±10%, 1/2W	108134	
R213	Resistor, composition, 180K ±10%, 1/2W	108431	
R214	Resistor, composition, 1K ±10%, 1/2W	108563	
R215	Resistor, composition, 3.3 Meg ±10%, 1/2W	108282	
R216	Resistor, composition, 1.5 Meg ±10%, 1/2W	108175	
R217	Resistor, composition, 4.7K ±10%, 1/2W	108381	
R218	Resistor, composition, 22K ±10%, 1/2W	108209	
R219	Resistor, composition, 220Ω ±10%, 1/2W	108191	
R220	Resistor, carbon film, 10Ω ±1%, 1/2W	107789	
R221	Resistor, carbon film, 75Ω, ±1%, 1/2W	107045	
R222	Resistor, variable wirewound 500Ω ±10%, 2W	111773	
R223, R224	Resistor, composition, 1.8K ±10%, 1/2W	108860	
R225, R226	Resistor, composition, 47K ±10%, 2W	110015	
R227	Resistor, composition, 2.2K ±10%, 2W	109967	
R228	Resistor, composition, 560K ±10%, 1/2W	108795	
R229	Resistor, composition, 560Ω ±10%, 1/2W	108316	
R230	Resistor, composition, 2.2K ±10%, 2W	109967	
R231	Resistor, composition, 180K ±10%, 1/2W	108431	
R232	Resistor, variable wirewound, 10K ±20%, 2W	111617	
R233	Resistor, composition, 100K ±10%, 1/2W	108126	
R234	Resistor, carbon film, 2.7K ±1%, 1/2W	107276	
R235	Resistor, carbon film, 31.6K ±1%, 1W	107797	
R236	Resistor, composition, 22K ±10%, 1/2W (may be omitted)	108209	
V201	Lamp, neon glow, type NE2E, 1/10W	100347	
V202	Vacuum tube, duo triode, 5751	116657	
V203	Vacuum tube, triode-pentode, 6AW8A	116434	
V204	Vacuum tube, voltage reference, OA2	115873	

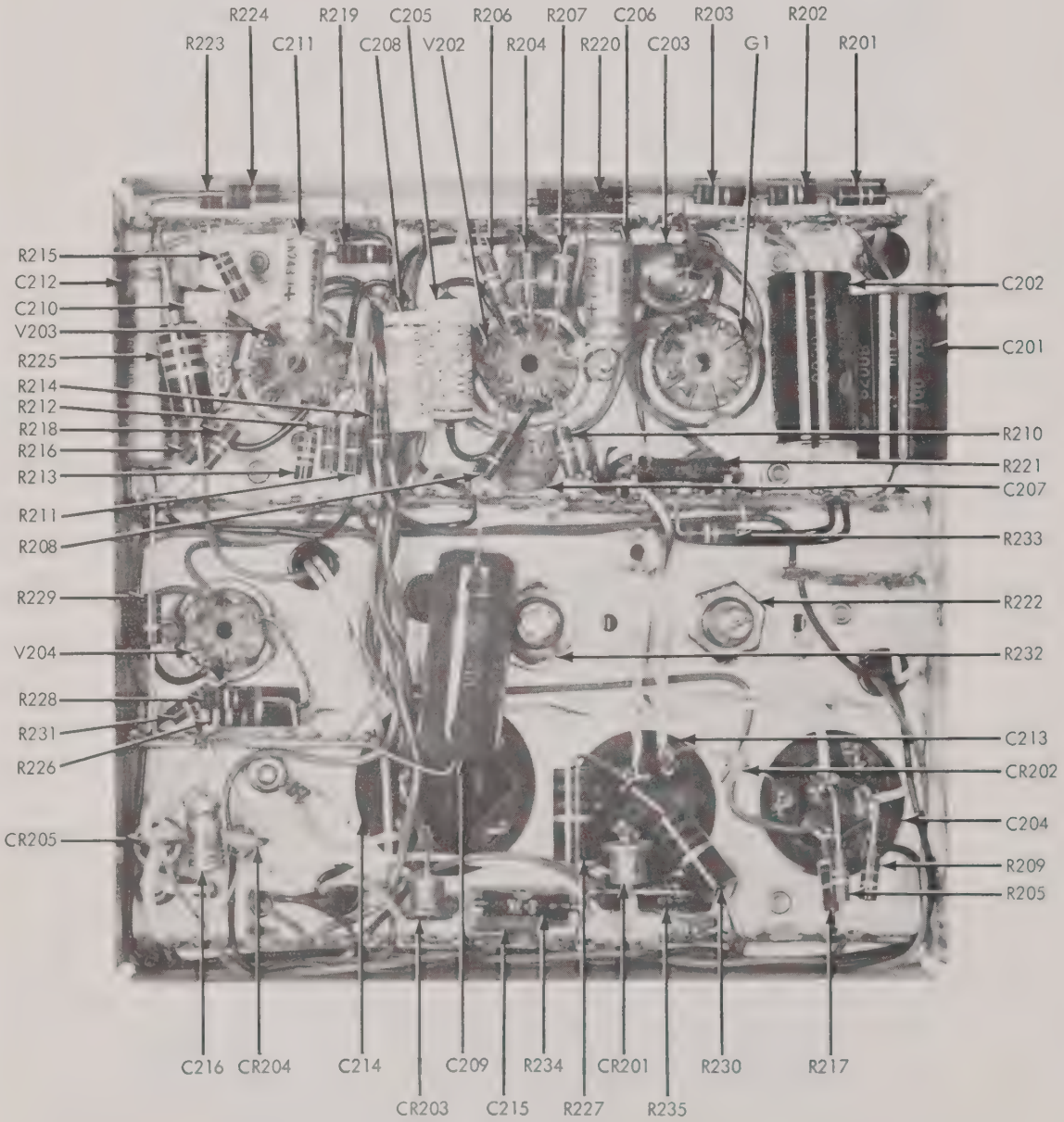

Figure 5-4. NULL DETECTOR ASSEMBLY (Sheet 1 of 2)

REFERENCE DESIGNATION	DESCRIPTION	FLUKE STOCK NO.	USE CODE
	NOTE: This assembly applies to 821A & 821A/AG serial numbers 422 and on and 821AR & 821AR/AG serial numbers 373 and on.		
	Null Detector Board Assembly	168807	
	Chopper Drive Assembly	168815	
C212	Capacitor, plastic, 0.047 uf ±20%, 100V	106096	
DS202, DS203	Lamp, neon glow, type NE2U	*162602	
R226	Resistor, variable composition, 100K ±30%, 3/10W	163402	
R227, R228	Resistor, composition, 390K ±10%, 1/2W	108993	
C201, C202	Capacitor, electrolytic, 0.22 uf ±20%, 100V coated with epoxy resin	167452	
C203	Capacitor, plastic, 0.047 uf ±20%, 100V (Use 162008) Capacitor, plastic, 0.047 uf ±20%, 250V	106096 162008	K L
C204	Capacitor, ceramic, 180 pf ±10%, 500V	105890	
C205	Capacitor, electrolytic, 1250 uf -10/+50%, 4V	166330	
C206	Capacitor, electrolytic, 400 uf -10/+50%, 25V	168153	
C207	Capacitor, plastic, 0.1 uf ±10%, 200V	106013	
C208	Capacitor, plastic, 0.0047 uf ±20%, 200V	106054	
C209	Capacitor, electrolytic, 5 uf -10/+75%, 25V	152009	
C210	Capacitor, electrolytic, 1250 uf -10/+50%, 4V	166330	
C211	Capacitor, electrolytic, 10 uf -10/+50%, 25V	170266	
C213, C214	Capacitor, electrolytic, 400 uf -10/+50%, 25V	168153	
CR201 thru CR203	Diode, silicon, 1 Amp, 100 PIV	116111	
DS201	Lamp, neon glow, type NE2U coated with epoxy resin	*162776	
Q201	Transistor, silicon, NPN, Type S7563 (Use 177105) Transistor, silicon, NPN, Type 2N3565	168716 177105	K L
Q202 to Q206	Transistor, silicon, NPN, Type 2N3391	168708	
Q207	Transistor, silicon, PNP, Type 2N3638	169375	
R201	Resistor, composition, 270K ±10%, 1W (Use 110023) Resistor, composition, 270K ±10%, 2W	109512 110023	K L
R202	Resistor, composition, 470K ±10%, 1/2W	108290	
R203	Resistor, metal film, 10.7Ω ±1%, 1/2W	168740	
R204	Resistor, composition, 68Ω ±10%, 1/2W	108464	

REFERENCE DESIGNATION	DESCRIPTION	FLUKE STOCK NO.	USE CODE
R205	Resistor, variable wirewound, 500Ω ±10%, 1-1/4W	112433	
R206	Resistor, composition, 10K ±10%, 1/2W	108118	
R207	Resistor, composition, 1M ±10%, 1/2W	108134	
R208	Resistor, composition, 10M ±10%, 1/2W	108142	
R209	Resistor, composition, 100K ±10%, 1/2W	108126	
R210	Resistor, composition, 2.2M ±10%, 1/2W	108225	
R211	Resistor, composition, 270K ±10%, 1/2W	108258	
R212	Resistor, variable composition, 100K ±20%, 1/4W	163873	
R213	Resistor, composition, 10Ω ±10%, 1/2W	108092	
R214	Resistor, composition, 180K ±10%, 1/2W	108431	
R215	Resistor, composition, 10K ±10%, 1/2W	108118	
R216	Resistor, composition, 180K ±10%, 1/2W	108431	
R217	Resistor, composition, 100K ±10%, 1/2W	108126	
R218	Resistor, composition, 27K ±10%, 1/2W	108878	
R219	Resistor, composition, 47K ±10%, 1/2W	108480	
R220	Resistor, composition, 100Ω ±10%, 1/2W	108100	
	Resistor, composition, 220Ω ±10%, 1/2W	108191	
R221	Resistor, composition, 270K ±10%, 1/2W	108258	
R222	Resistor, composition, 18K ±10%, 1/2W	108183	
R223	Resistor, composition, 2.2K ±10%, 1/2W	108605	
R224, R225	Resistor, composition, 47K ±10%, 1/2W	108480	
R229	Resistor, composition, 100Ω ±10%, 1/2W	108100	
R230	Resistor, composition, 47K ±10%, 1/2W	108480	
V201, V202	Photoelectric cell	167940	
V203	Photoelectric cell	167940	K
	Photoelectric cell	200261	L

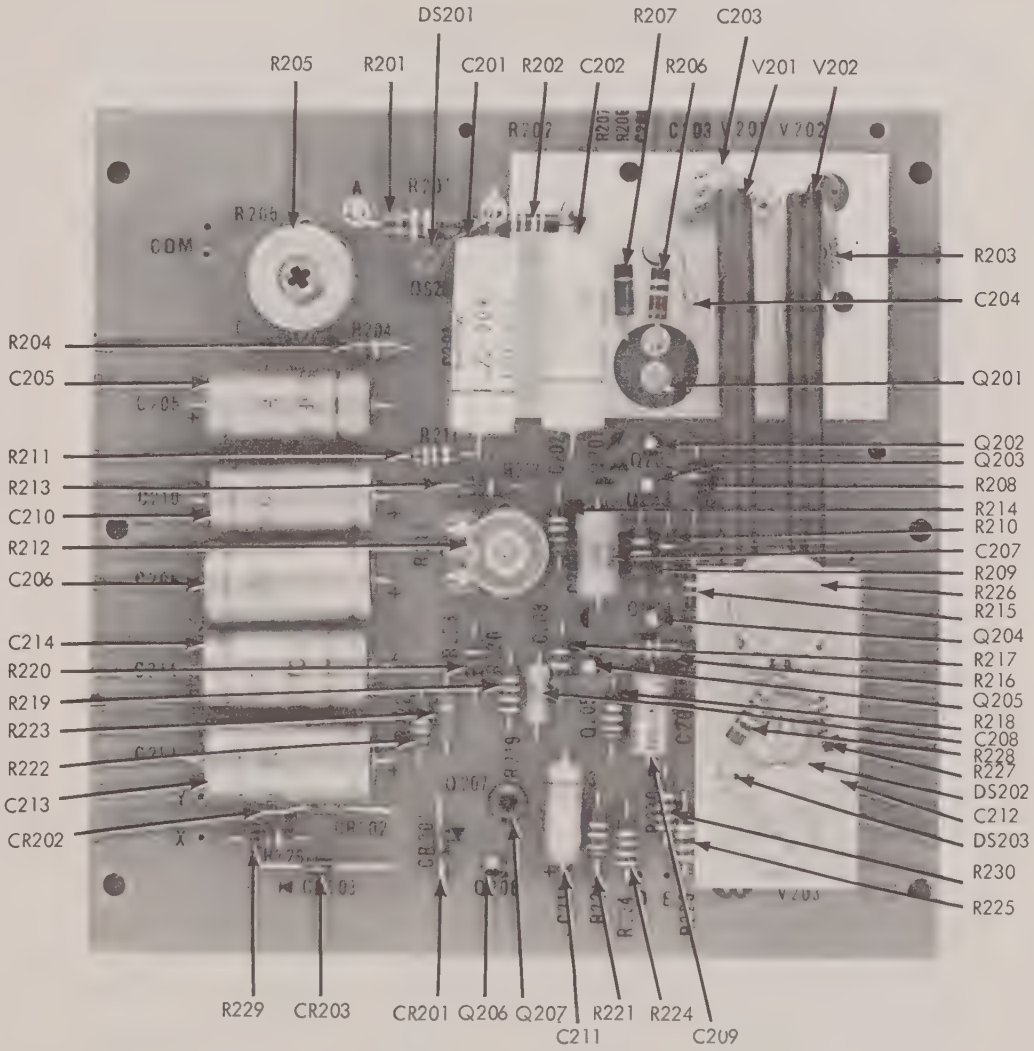

Figure 5-4. NULL DETECTOR ASSEMBLY (sheet 2 of 2)

REFERENCE DESIGNATION	DESCRIPTION	FLUKE STOCK NO.	USE CODE
	Range Resistor Board Assembly (821A) (821AR) (821A/AG) (821AR/AG)	*121343 *125344 *163519 *163659	
C301	Capacitor, plastic, 1 uf ±20%, 600V	105924	
C302	Capacitor, plastic, 2 uf ±20%, 200V	106443	
R311 thru R315	Resistor, composition, 22 Meg ±10%, 1/2W	108233	
R318	Resistor, variable wirewound, 350Ω ±10%, 1-1/4W	113100	
R322	Resistor, composition, 12K ±10%, 1/2W	108977	
R323, R326, R329	Resistor, variable wirewound, 150Ω ±10%, 1-1/4W	113092	
R331	Resistor, composition, 270Ω ±10%, 1/2W	108241	
	Matched Resistor Set (821A and 821AR)	*121400	
R316, R317	Resistor, wirewound, 74.975K ±0.015%, 1/2W	**	
R319	Resistor, wirewound, 459.8Ω ±0.025%, 1/2W	**	
R320, R321	Resistor, wirewound, 74.975K ±0.015%, 1/2W	**	
R324	Resistor, wirewound, 28.571K ±0.015%, 1/2W	**	
R327	Resistor, wirewound, 2298.8Ω ±0.015%, 1/8W	**	
R328	Resistor, wirewound, 74.975K ±0.015%, 1/2W	**	
R330	Resistor, wirewound, 225.45Ω ±0.015%, 1/8W	**	
R332	Resistor, wirewound, 74.975K ±0.015%, 1/2W	**	
	Zener-Resistor Set (821A/AG and 821AR/AG)		
CR301	Zener Diode (If replacement is required, CR301, R14, R15, R316, R317, R319, and R332 must be replaced with Zener-resistor replacement set 184358.		
R13	Resistor, composition, 4.7K ±10%, 1/2W	108381	
R14	Resistor, composition (Optimum value is selected at factory to match Zener diode. If replacement is required, replace with a resistor of same value as determined by color code.)		
R15	Resistor, wirewound (Optimum value is selected at factory to match Zener diode)	**	
R316, R317	Resistor, wirewound, 74.975K ±0.015%, 1/2W	**	
R319	Resistor, wirewound, 2778 to 2964.45Ω, 0.02W (Optimum value is selected at factory to match Zener diode)	**	
R320, R321	Resistor, wirewound, 74.975K ±0.015%, 1/2W	**	
R324	Resistor, wirewound, 28.571K ±0.015%, 1/2W	**	
R327	Resistor, wirewound, 2298.8Ω ±0.015%, 1/8W	**	
R328	Resistor, wirewound, 74.975K ±0.015%, 1/2W	**	
R330	Resistor, wirewound, 225.45Ω ±0.015%, 1/8W	**	
R332	Resistor, wirewound, 74.975K ±0.015%, 1/2W	**	
	Plastic cover	*121442	

**These resistors are factory matched for each instrument. When ordering, include all information stamped on resistor.

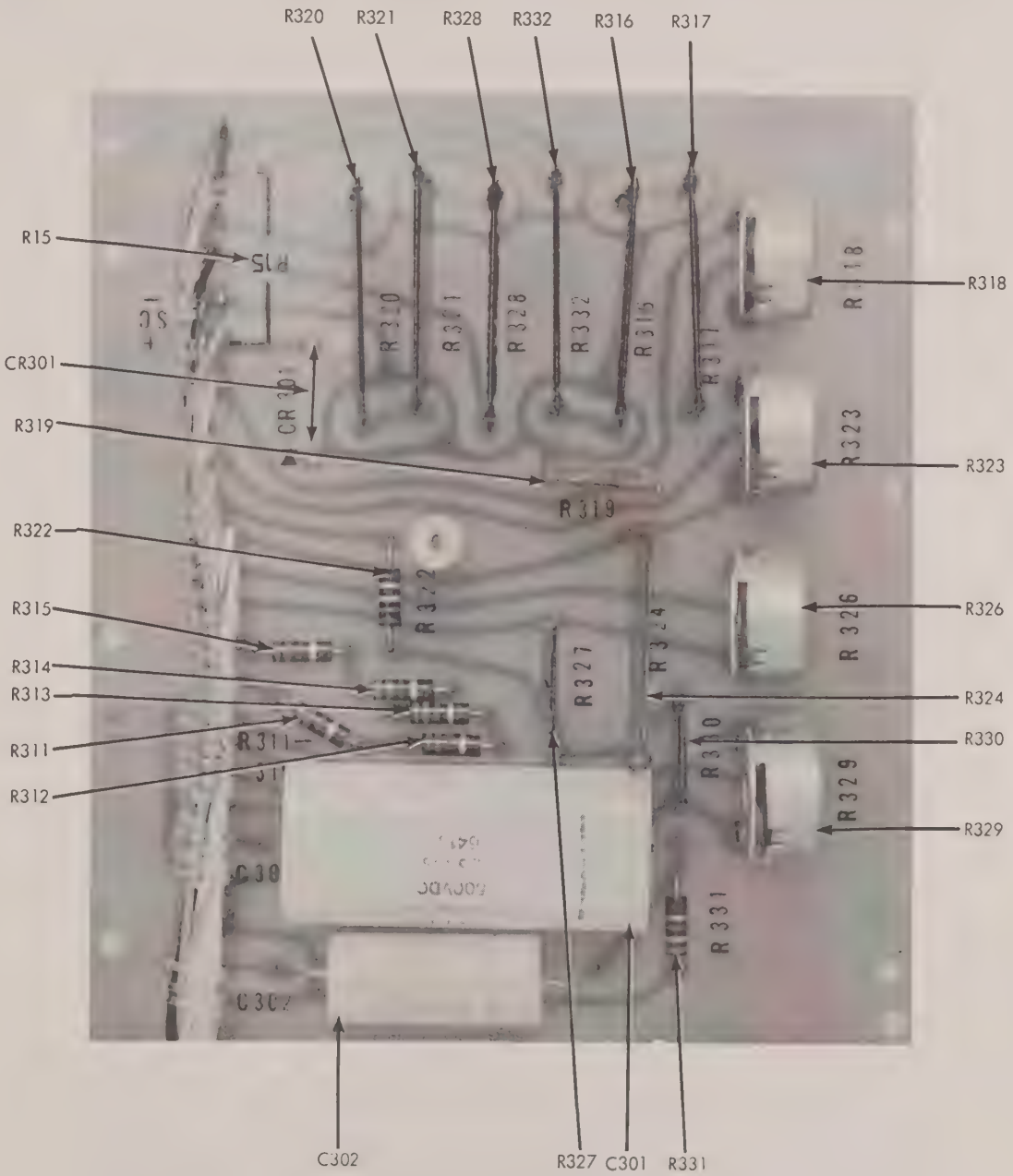

Figure 5-5. RANGE RESISTOR BOARD ASSEMBLY

REFERENCE DESIGNATION	DESCRIPTION	FLUKE STOCK NO.	USE CODE
	Kelvin Varley Resistor Board Assembly	*121376	
R401 thru R406	Resistor, wirewound 40K ±0.02%, 1/2W	**	
R407 thru R417	Resistor, wirewound 8K ±0.005%, 1/2W	**	
R418 thru R428	Resistor, wirewound 1.6K ±0.01%, 1/8W	**	
R429 thru R439	Resistor, wirewound 320Ω ±0.02%, 1/8W	** **	
R440 thru R449	Resistor, wirewound 64Ω ±0.1%, 1/8W	**	
R450 thru R455	Resistor, variable wirewound, 10Ω ±20%, 1-1/4W	112672	
	Plastic cover	147595	

**These resistors are factory matched for each instrument. When ordering, include all information stamped on resistor.

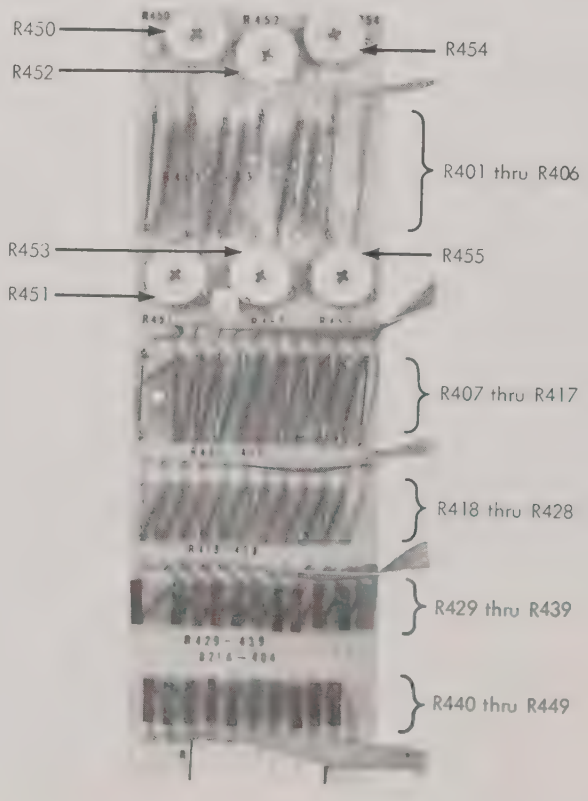

Figure 5-6. KELVIN-VARLEY RESISTOR BOARD ASSEMBLY

REFERENCE DESIGNATION	DESCRIPTION	FLUKE STOCK NO.	USE CODE
	Chopper Drive Assembly	*125211	I
C701	Capacitor, plastic, 0.18 uf ±10%, 200V	105874	I
C702, C703	Capacitor, electrolytic, 20 uf -10/+100%, 50V	106229	I
C704	Capacitor, plastic, 0.18 uf ±10%, 200V	105874	I
Q701, Q702	Transistor, germanium, PNP, 2N1379	117143	I
Q703, Q704	Transistor, germanium, PNP, 2N1372	116129	I
R701	Resistor, deposited carbon, 44.2K ±1%, 1/2W	107912	I
R702	Resistor, composition, 120Ω ±10%, 1/2W	108696	I
R703	Resistor, deposited carbon, 44.2K ±1%, 1/2W	107912	I
R704, R705	Resistor, variable wirewound, 10K ±20%, 1-1/4W	112862	I
R706, R707	Resistor, composition, 820Ω ±10%, 1/2W	108423	I
R708, R709	Resistor, composition, 120Ω ±10%, 1W	109827	I

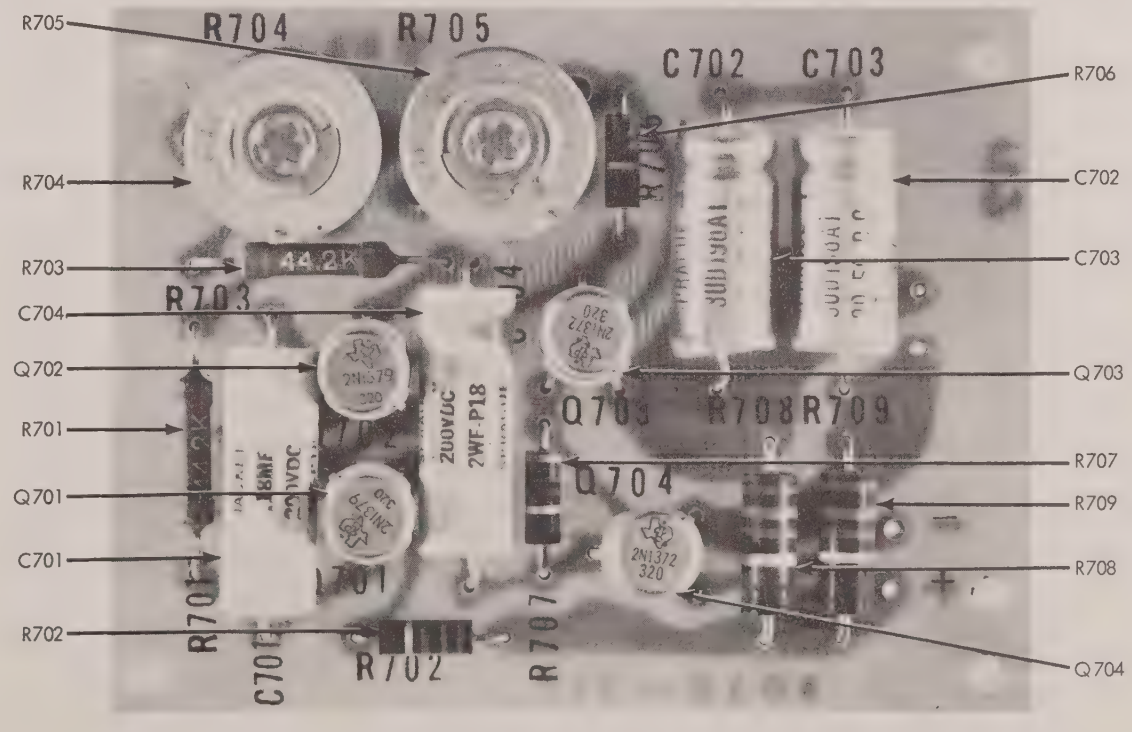

Figure 5-7. CHOPPER DRIVE ASSEMBLY

USE CODE EFFECTIVITY

The following list of use codes is intended to allow the customer to determine the effectivity of all replaceable parts. All parts with no code are used on all instruments with serial numbers above 123. New codes will be added as necessary on forthcoming instruments.

USE CODE	EFFECTIVITY
No Code	Model 821A serial number 123 and on Model 821AR serial number 123 and on Model 821A/AG serial number 123 and on Model 821AR/AG serial number 123 and on
A	Model 821A serial number 123 thru 251 Model 821AR serial number 123 thru 197 Model 821A/AG serial number 123 thru 251 Model 821AR/AG serial number 123 thru 197
B	Model 821A serial number 252 and on Model 821AR serial number 198 and on Model 821A/AG serial number 252 and on Model 821AR/AG serial number 198 and on
C	Model 821A serial number 123 thru 266 Model 821AR serial number 123 thru 255 Model 821A/AG serial number 123 thru 266 Model 821AR/AG serial number 123 thru 255
D	Model 821A serial number 267 and on Model 821AR serial number 256 and on Model 821A/AG serial number 267 and on Model 821AR/AG serial number 256 and on
E	Model 821A serial number 123 thru 422 Model 821AR serial number 123 thru 273 Model 821A/AG serial number 123 thru 422 Model 821AR/AG serial number 123 thru 273
F	Model 821A serial number 423 and on Model 821AR serial number 274 and on Model 821A/AG serial number 423 and on Model 821AR/AG serial number 274 and on
G	Model 821A serial number 123 thru 423 Model 821AR serial number 123 thru 374 Model 821A/AG serial number 123 thru 423 Model 821AR/AG serial number 123 thru 374
H	Model 821A serial number 424 and on Model 821AR serial number 375 and on Model 821A/AG serial number 424 and on Model 821AR/AG serial number 375 and on
I	Model 821A serial number 123 thru 421 Model 821AR serial number 123 thru 372 Model 821A/AG serial number 123 thru 421 Model 821AR/AG serial number 123 thru 372
J	Model 821A serial number 422 and on Model 821AR serial number 373 and on Model 821A/AG serial number 422 and on Model 821AR/AG serial number 373 and on
K	Model 821A serial number 123 thru 468 Model 821AR serial number 123 thru 398 Model 821A/AG serial number 123 thru 468 Model 821AR/AG serial number 123 thru 398
L	Model 821A serial number 469 and on Model 821AR serial number 399 and on Model 821A/AG serial number 469 and on Model 821AR/AG serial number 399 and on

APPENDIX A

FEDERAL SUPPLY CODE FOR MANUFACTURERS

A-1. CODE TO NAME

A-2. The following five-digit code numbers are listed in numerical sequence along with the manufacturer's name and address to which the code has been assigned. The Federal Supply Code has been taken from Cataloging Handbook H 4-2, Code to Name.

00213	Sage Electronics Corp. Rochester, New York
00327	Welwyn International, Inc. Westlake, Ohio
00656	Aerovox Corp New Bedford, Massachusetts
00779	AMP Inc. Harrisberg, Pennsylvania
01121	Allen-Bradley Co. Milwaukee, Wisconsin
01281	TRW Semiconductors Lawndale, California
01295	Texas Instruments, Inc. Semiconductor Components Div. Dallas, Texas
01686	RCL Electronics Inc. Manchester, New Hampshire
01730	Deleted
01884	Dearborn Electronics Inc. Orlando, Florida
02114	Ferroxcube Corp Saugerties, New York
02606	Replaced by 15801
02660	Amphenol-Borg Elect. Corp. Broadview, Illinois
02799	Arco Capacitors, Inc. Los Angeles, California
03614	Replaced by 71400
03651	Replaced by 44655
03797	Eldema Corp. Compton, California
03877	Transitron Electronic Corp. Wakefield, Massachusetts
03888	Pyrofilm Resistor Co., Inc. Cedar Knolls, New Jersey
03911	Clairex Corp. New York, New York
03980	Muirhead Instruments, Inc. Mountainside, New Jersey
04009	Arrow Hart and Hegeman Electronic Company Hartford, Connecticut
04062	Replaced by 72136
04202	Replaced by 81312
04217	Essex Wire Corp Wire & Cable Div. Anaheim, California
04221	Aemco Div. of Midtex Inc. Mankato, Minnesota
04645	Replaced by 75376
04713	Motorola Semiconductor Products Inc. Phoenix, Arizona
05082	Replaced by 94154
05236	Jonathan Mfg. Co. Fullerton, California
05277	Westinghouse Electric Corp. Semiconductor Dept. Youngwood, Pennsylvania
05278	Replaced by 43543
05397	Union Carbide Corp. Electronics Div. Cleveland, Ohio
05571	Sprague Electric Co Pacific Div. Los Angeles, California
05704	Alac, Inc. Glendale, California
05820	Wakefield Engineering Ind. Wakefield, Massachusetts
06001	General Electric Company Capacitor Department Irmo, South Carolina
06136	Replaced by 63743
06473	Amphenol Space & Missile Sys. Chatsworth, California
06555	Beede Electrical Instrument Co. Penacook, New Hampshire
06739	Electron Corp. Littletown, Colorado
06743	Clevite Corp. Cleveland, Ohio
06751	Semcor Div. Components Phoenix, Arizona
06860	Gould National Batteries Inc. City of Industry, California
06980	Eitel-McCullough, Inc. San Carlos, California
07115	Replaced by 14674
07138	Westinghouse Electric Corp Electronic Tube Div. Elmira, New York
07263	Fairchild Semiconductor Div. of Fairchild Camera & Instrument Corp. Mountain View, California
07344	Bircher Co., Inc. Rochester, New York
07792	Lerma Engineering Corp Northampton, Massachusetts
07910	Continental Device Corp. Hawthorne, California
08530	Reliance Mica Corp. Brooklyn, New York
08792	CBS Electronics Semiconductor Operations-Div. of CBS Inc. Lowell, Massachusetts
08806	General Electric Co. Miniature Lamp Dept. Cleveland, Ohio
08863	Nylomatic Corp. Norrisville, Pennsylvania
08988	Skottie Electronics Inc. Archbald, Pennsylvania
09922	Burndy Corp. Norwalk, Connecticut
11237	Chicago Telephone of Calif. Inc. South Pasadena, California
11358	CBS Electronics Div. of CBS Inc. Newburyport, Massachusetts
11403	Best Products Co. Chicago, Illinois
11503	Keystone Mfg Div. of Avis Industrial Corp. Warren, Michigan
12014	Chicago Rivet & Machine Co. Bellwood, Illinois
12040	National Semiconductor Corp. Danburry, Connecticut
12060	Diodes, Inc. Chatsworth, California
12136	Philadelphia Handle Co. Camden, New Jersey
12323	Presin Co., Inc. Shelton, Connecticut
12327	Freeway Washer & Stamping Co. Cleveland, Ohio
12400	Replaced by 75042
12617	Hamlin Inc. Lake Mills, Wisconsin
12697	Clarostat Mfg. Co. Dover, New Hampshire
12749	James Electronics Chicago, Illinois

12856 Micrometals
Sierra Madre, California

12954 Dickson Electronics Corp.
Scottsdale, Arizona

13606 Sprague Electric Co.
Transistor Div.
Concord, New Hampshire

13839 Replaced by 23732

14099 Semtech Corp.
Newbury Park, California

14193 California Resistor Corp.
Santa Monica, California

14298 American Components, Inc.
Conshohocken, Pennsylvania

14655 Cornell-Dubilier Electronics
Newark, New Jersey

14674 Corning Glass Works
Corning, New York

14752 Electro Cube Inc.
San Gabriel, California

14869 Replaced by 96853

15636 Elec-Trol Inc.
Northridge, California

15801 Fenwal Electronics Inc.
Framingham, Massachusetts

15818 Amelco Semiconductor
Div. of Teledyne Inc.
Mountain View, California

15849 Useco, Inc.
Mt. Vernon, New York

15909 Replaced by 17870

16332 Replaced by 28478

16473 Cambridge Scientific Ind. Inc.
Cambridge, Maryland

16742 Paramount Plastics
Downey, California

16758 Delco Radio
Div. of General Motors
Kokomo, Indiana

17069 Circuit Structures Lab.
Upland, California

17856 Siliconix, Inc.
Sunnyvale, California

17870 Daven-Div. of Thomas A. Edison
Ind. --McGraw-Edison Co.
Manchester, New Hampshire

18083 Deleted

18178 Vactec Inc.
Maryland Heights, Missouri

18736 Voltronics Corp.
Hanover, New Jersey

19429 Montronics, Inc.
Seattle, Washington

19451 Perine Machinery & Supply Co.
Seattle, Washington

19701 Electra Mfg. Co.
Independence, Kansas

20584 Enochs Mfg. Co.
Indianapolis, Indiana

22767 ITT Semiconductors
Div. of ITT
Palo Alto, California

23732 Tracor
Rockville, Maryland

24246 Southco
Div. of South Chester Corp.
Lester, Pennsylvania

24655 General Radio Co.
West Concord, Massachusetts

25403 Amperex Electronic Corp
Semiconductor & Receiving
Tube Division
Slatersville, Rhode Island

28478 Deltrol Controls Corp.
Milwaukee, Wisconsin

28520 Heyman Mfg. Co.
Kenilworth, New Jersey

30323 Illinois Tool Works Inc.
Chicago, Illinois

33173 General Electric Co.
Tube Dept.
Owensboro, Kentucky

37942 Mallory, P. R., & Co., Inc.
Indianapolis, Indiana

38315 Honeywell Inc.
Precision Meter Div.
Manchester, New Hampshire

42498 National Company
Melrose, Massachusetts

43543 Nytronics Inc.
Transformer Co. Div.
Alpha, New Jersey

44655 Ohmite Mfg. Co
Skokie, Illinois

49671 Radio Corp. of America
New York, New York

49956 Raytheon Company
Lexington, Maine

53021 Sangamo Electric Co.
Springfield, Illinois

55026 Simpson Electric Company
Chicago, Illinois

56289 Sprague Electric Co.
North Adams, Massachusetts

58474 Superior Electric Co.
Bristol, Connecticut

60399 Torrington Mfg. Co.
Torrington, Connecticut

62460 Deleted

63743 Ward Leonard Electric Co.
Mount Vernon, New York

64834 West Mfg. Co.
San Francisco, California

65092 Weston Instruments Inc.
Newark, New Jersey

66150 Winslow Tele-Tronics Inc.
Asbury Park, New Jersey

70563 Amperite Company
Union City, New Jersey

70903 Belden Mfg. Co.
Chicago, Illinois

71002 Birnbach Radio Co., Inc.
New York, New York

71400 Bussmann Mfg.
Div. of McGraw-Edison Co.
St. Louis, Missouri

71450 CTS Corp.
Elkhart, Indiana

71468 ITT Cannon Electric Inc.
Los Angeles, California

71482 Clare, C P & Co.
Chicago, Illinois

71590 Centralab
Div. of Globe Union Inc.
Milwaukee, Wisconsin

71707 Coto Coil Co., Inc.
Providence, Rhode Island

71744 Chicago Miniature Lamp Works
Chicago, Illinois

71785 Cinch Mfg. Co. & Howard
B Jones Div.
Chicago, Illinois

72005 Driver, Wilbur B., Co.
Newark, New Jersey

72092 Replaced by 06980

72136 Electro Motive Mfg. Co.
Willimantic, Connecticut

72259 Nytronics Inc.
Berkeley Heights, New Jersey

72354 Deleted

72619 Dialight Corp
Brooklyn, New York

72653 G. C. Electronics
Rockford, Illinois

72665 Replaced by 90303

72794 Dzus Fastener Co., Inc.
West Islip, New York

72928 Gudeman Co.
Chicago, Illinois

72982 Erie Tech. Products Inc.
Erie, Pennsylvania

73138 Beckman Instruments Inc.
Helipot Division
Fullerton, California

73293 Hughes Aircraft Co.
Electron Dynamics Div.
Newport Beach, California

73445 Amperex Electronic Corp.
Hicksville, New York

73559 Carling Electric Inc.
Hartford, Connecticut

73586 Circle F Industries
Trenton, New Jersey

73734 Federal Screw Products, Inc.
Chicago, Illinois

73743 Fischer Special Mfg. Co.
Cincinnati, Ohio

73899 JFD Electronics Co.
Brooklyn, New York

73949 Guardian Electric Mfg. Co.
Chicago, Illinois

74199 Quan-Nichols Co.
Chicago, Illinois

74217 Radio Switch Corp.
Marlboro, New Jersey

74276 Signalite Inc.
Neptune, New Jersey

74306 Piezo Crystal Co.
Carlisle, Pennsylvania

74542 Hoyt Elect. Instr. Works
Penacook, New Hampshire

74970 Johnson, E. F., Co.
Waseca, Minnesota

75042 IRC Inc.
Philadelphia, Pennsylvania

75376 Kurz-Kasch, Inc.
Dayton, Ohio

75382 Kulka Electric Corp.
Mt. Vernon, New York

75915 Littlefuse Inc.
Des Plaines, Illinois

76854 Oak Mfg. Co.
Crystal Lake, Illinois

77342 Potter & Brumfield
Div. of Amer. Machine & Foundry
Princeton, Indiana

77969 Rubbercraft Corp. of Calif. LTD
Torrance, California

78189	Shakeproof Div. of Illinois Tool Works Elgin, Illinois
78277	Sigma Instruments, Inc. South Braintree, Massachusetts
78488	Stackpole Carbon Co. St. Marys, Pennsylvania
78553	Tinnerman Products Cleveland, Ohio
79136	Waldes Kohinoor Inc. Long Island City, New York
79497	Western Rubber Company Goshen, Indiana
79963	Zierick Mfg. Corp. New Rochelle, New York
80031	Mepco Div. of Sessions Clock Co. Morristown, New Jersey
80145	API Instruments Co. Chesterland, Ohio
80183	Sprague Products North Adams, Massachusetts
80294	Bourns Inc. Riverside, California
80583	Hammarlund Co., Inc. Mars Hill, North Carolina
80640	Stevens, Arnold Inc. Boston, Massachusetts
81073	Grayhill Inc. La Grange, Illinois
81312	Winchester Electronics Div. of Litton Industries Oakville, Connecticut
81439	Therm-O-Disc Inc. Mansfield, Ohio
81483	International Rectifier Corp. El Segundo, California
81590	Korry Mfg Co. Seattle, Washington
82376	Deleted
82389	Switchcraft Inc. Chicago, Illinois
82415	Price Electric Corp. Frederick, Maryland
82872	Roanwell Corp. New York, New York
82877	Rotron Mfg. Co., Inc. Woodstock, New York
82879	ITT Wire & Cable Div. Pawtucket, Rhode Island
83003	Varo Inc. Garland, Texas
83298	Bendix Corp. Electric Power Division Eatontown, New Jersey
83330	Smith, Herman H., Inc. Brooklyn, New York
83478	Rubbercraft Corp. of America New Haven, Connecticut
83594	Burroughs Corp. Electronic Components Div. Plainfield, New Jersey
83740	Union Carbide Corp. Consumer Products Div. New York, New York
84171	Arco Electronics, Inc. Great Neck, New York
84411	TRW Ogallala, Nebraska
86577	Precision Metal Products Stoneham, Massachusetts
86684	Radio Corp. of America Electronic Components & Devices Harrison, New Jersey
86689	Deleted
87034	Marco-Oak Inc. Anaheim, California
88419	Use 14655
88690	Replaced by 04217
89536	Fluke, John Mfg. Co., Inc. Seattle, Washington
89730	Replaced by 08806
90201	Mallory Capacitor Co. Indianapolis, Indiana
90215	Best Stamp & Mfg. Co. Kansas City, Missouri
90211	Square D Co. Chicago, Illinois
90303	Mallory Battery Co. Tarrytown, New York
91293	Johanson Mfg. Co. Boonton, New Jersey
91407	Replaced by 58474
91637	Dale Electronics Inc. Columbus, Nebraska
91662	Elco Corp. Willow Grove, Pennsylvania
91737	Gremar Mfg. Co., Inc. Wakefield, Massachusetts
91802	Industrial Devices, Inc. Edgewater, New Jersey
91836	King's Electronics Tuckahoe, New York
91929	Honeywell Inc. Micro Switch Div. Freeport, Illinois
91934	Miller Electric Co., Inc. Pawtucket, Rhode Island
93332	Sylvania Electric Products Semiconductor Products Div. Woburn, Massachusetts
94145	Replaced by 49956
94154	Tung-Sol Div. of Wagner Electric Corp. Newark, New Jersey
95146	Alco Electronics Products Inc. Lawrence, Massachusetts
95263	Leecraft Mfg. Co. Long Island City, New York
95264	Replaced by 98278
95275	Vitramon Inc. Bridgeport, Connecticut
95303	Radio Corp. of America Solid State & Receiving Tube Div. Cincinnati, Ohio
95354	Methode Mfg. Corp. Rolling Meadows, Illinois
95712	Dage Electric Co., Inc. Franklin, Indiana
95987	Weckesser Co., Inc. Chicago, Illinois
96733	San Fernando Electric Mfg. Co. San Fernando, California
96853	Rustrak Instrument Co. Manchester, New Hampshire
96881	Thomson Industries, Inc. Manhasset, New York
97540	Master Mobile Mounts Div. of Whitehall Electronics Corp. Los Angeles, California
97913	Industrial Electronic Hdware Corp. New York, New York
97945	White, S. S. Co. Plastics Div. New York, New York
97966	Replaced by 11358
98094	Replaced by 49956
98278	Microdot Inc. Pasadena, California
98291	Sealectro Corp. Conhex Div Mamaroneck New York
98388	Accurate Rubber & Plastics Culver City, California
98743	Replaced by 12749
98925	Deleted
99120	Plastic Capacitors, Inc. Chicago, Illinois
99217	Southern Electronics Corp. Burbank, California
99515	Marshall Industries Capacitor Div. Monrovia, California

Revised August 1, 1968
Using H4-1 and H4-2
Dated June , 1968

WARRANTY

The JOHN FLUKE MFG. CO., INC. warrants each instrument manufactured by them to be free from defects in material and workmanship. Their obligation under this Warranty is limited to servicing or adjusting an instrument returned to the factory for that purpose, and to making good at the factory any part or parts thereof; except tubes, fuses, choppers and batteries, which shall, within one year after making delivery to the original purchaser, be returned by the original purchaser with transportation charges prepaid, and which upon their examination shall disclose to their satisfaction to have been thus defective. If the fault has been caused by misuse or abnormal conditions of operation, repairs will be billed at a nominal cost. In this case, an estimate will be submitted before work is started, if requested.

If any fault develops, the following steps should be taken.

1. Notify the John Fluke Mfg. Co., Inc., giving full details of the difficulty, and include the Model number, type number, and serial number. On receipt of this information, service data or shipping instructions will be forwarded to you.

2. On receipt of the shipping instructions, forward the instrument prepaid, and repairs will be made at the factory. If requested, an estimate of the charges will be made before the work begins, provided the instrument is not covered by the Warranty.

SHIPPING

All shipments of John Fluke Mfg. Co., Inc. instruments should be made via Railway Express prepaid. The instrument should be shipped in the original packing carton; or if it is not available, use any suitable container that is rigid. If a substitute container is used, the instrument should be wrapped in paper and surrounded with at least four inches of excelsior or similar shock-absorbing material.

CLAIM FOR DAMAGE IN SHIPMENT

The instrument should be thoroughly inspected immediately upon receipt. All material in the container should be checked against the enclosed packing list. The manufacturer will not be responsible for shortages against the packing sheet unless notified immediately. If the instrument fails to operate properly, or is damaged in any way, a claim should be filed with the carrier. A full report of the damage should be obtained by the claim agent, and this report should be forwarded to John Fluke Mfg. Co., Inc. Upon receipt of this report you will be advised of the disposition of the equipment for repair or replacement. Include the model number, type number, and serial number when referring to this instrument for any reason.

The John Fluke Mfg. Co., Inc. will be happy to answer all application questions which will enhance your use of this instrument. Please address your requests to:

JOHN FLUKE MFG. CO., INC., P. O. BOX 7428, SEATTLE 33, WASHINGTON

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Rosemont, Illinois 60018
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Zip 46234

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Kensington, Maryland 20795
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Plainview, Long Island 11803
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Zip 44135

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Pittsburgh, Pa, 15236
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Allan Crawford Associates, Ltd.
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Santiago, Chile

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Helsinki 52, Finland

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92 Levallois
Perret, France

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Hong Kong

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Tel-Aviv, Israel

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20146 Milano, Italy

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Osaka, Japan

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Seoul, Korea

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East Malaysia

P. O. Box 91
Pataling Jaya
West Malaysia

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Eugenia 408
Departments 1 y 5
Mexico 12, D. F.

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Post Office Box 4542
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Fluke (Nederland) N. V.
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Tilburg, The Netherlands

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Oslo 6, Norway

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Robinson Road
Singapore, Singapore

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Sabana Grande No. 1
Caracas, Venezuela

Rev. 9/70

In Europe contact FLUKE NEDERLAND, N. V., Post Office Box 5053, Tilburg, The Netherlands

List of Factory Authorized Service Centers

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Arizona Standards Laboratory
4430 N. 19th Ave.
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P. O. Box 4339, Station A
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1001 E. 55th St.
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Fluke International Corp
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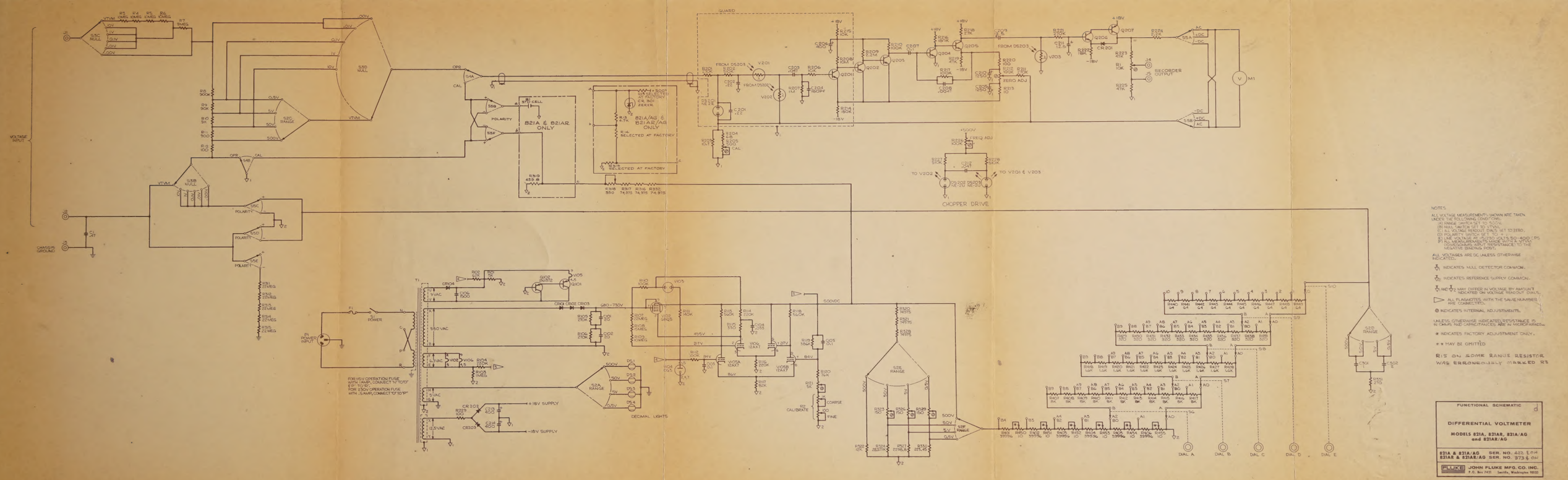
For information regarding service centers in other foreign locations, contact the nearest Sales and Service Representative in your area.



NOTES

ALL VOLTAGE MEASUREMENTS SHOWN ARE TAKEN UNDER THE FOLLOWING CONDITIONS:
(A) RANGE SWITCH SET TO 500V.
(B) NULL SWITCH SET TO 470VΩ.
(C) ALL VOLTAGE READOUT DIALS SET TO ZERO.
(D) POLARITY SWITCH SET TO +.
(E) ALL MEASUREMENTS MADE WITH A 470VΩ VOLTMETER WITH